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PREFERENTIAL ABSORPTION OF CHOLESTEROL BY THE TOBACCO ARMYWORM *SPODOPTERA LITURA* (F.)

R. SAXENA, A. KUTHIALA & H. C. AGARWAL

Department of Zoology, University of Delhi, Delhi, India - 110 007

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The early sixth instar larvae of *Spodoptera litura* (F.) were fed on an artifical test diet containing two sterols simultaneously of which one was always ^{14}C-cholesterol and the other was either ^{3}H-sitosterol or ^{3}H-stigmasterol ^{3}H-campesterol. The concentration of cholesterol was fixed while that of other three sterols namely, sitosterol, stigmasterol and campesterol varied from one half to ten times that of cholesterol. The larvae were extracted 8, 12, 16, and 24 hours following feeding and ^{3}H and ^{14}C contents estimated. The incorporation of cholesterol was more than either of the three sterols tested ranging from 9.7 to 55 per cent. While the presence of sitosterol in the diet did not affect the absorption of cholesterol, the presence of stigmasterol or campesterol reduced the cholesterol absorption to less than half after 24 hours. Change in the proportions of the sterols in the sterol mixture adminisiered had very little effect on the per cent absorption of sterols from the diet of *S. litura* larvae.

(Key words : absorption, cholesterol, sitosterol, stigmasterol, campesterol, *Spodoptera litura)*

INTRODUCTION

Insects are incapable of *de novo* biosynthesis of sterols and must procure these from their diet for normal growth, development and reproduction (CLAYTON, 1964; GILBERT, 1967). The ubiquitous animal sterol, cholesterol, meets the sterol requirement of most of the insect species (HOUST, 1974). However, cholesterol can be substituted either wholly or partly by certain other sterols which may predominate in the diet and thereby may be responsible for the success or failure of the insect in establishing itself on the particular host. The common plant sterols- sitosterol, campesterol and stigmasterol which are closely related to cholesterol in structure, can replace cholesterol in many insects but the degree of their utilization varies from species to species.

Before any dietary sterol can be utilized it must be absorbed by the insect. Not much is, however, known about sterol absorption in insects, The house fly, *Musca domestica* and the beetle. *Dermestes maculatus* may selectively absorb some plant sterols in preference to others (KAPLANIS *et al.*, 1965; KATZ *et al.*, 1971). Studies of SVOBODA *et al.* (1979) on the sterols of *Trogoderma granarium* and its diet indicate a preferential absorption of cholesterol by this insect. The normal insect diet usually contains a mixture of sterols all of which may not be of much use to the insect. The insect may absorb different proportions of the sterols present according to its requirements. Not much, however is known about the preferences of the insects, if any, in terms of the relative rates of their absorption by the insects from the natural diet. Such studies were conducted with a polyphagous insect namely *Spodoptera litura* (Lepidoptera : Noctuidae).

MATERIALS AND METHODS

The larvae of *Spodoptera litura* were obtained from a colony maintained in the Department of Zoology, University of Delhi on freshly excised leaves of castor *(Ricinus communis)* at a temperature of 26±2°C, rh 70±5% and a photoperiod of 16L : 8D.

The experimental insects were fed on a cellulose and sucrose diet containing two labelled sterols simultaneously of which one was always 4-^{14}C-cholesterol (sp. act. 59.2 mCi/m mol) and the other was either ^{3}H-sitosterol (sp. act. 58 Ci/m mol, Radiochemical Centre, Amersham, U. K.) or ^{3}H-stigmasterol (sp. act. 220 cpm/μg) or ^{3}H-campesterol. (323 cpm μg courtsey of Dr. JAMES A. SVOBODA, Insect Pysiology, Laboratory, USDA, BARC, Beltsville, USA). The concentration of cholesterol used was 0.01 per cent diet whereas the concentrations of sitosterol / stigmasterol were either 0.005 or 0.01 or 0.1 per cent. Due to the non-availability of the radio-labelled campesterol in larger quantities, only equimolar concentration of 0.01 per cent campesterol was used. Five replicates were taken in each case. Early sixth instar larvae were starved for 24 hours and each larva was provided with 20 mg of the test diet which was consumed within five minutes. The insects were then allowed a sterol free diet of cellulose and sucrose *ad libitum*. These larvae were subsequently extracted for sterols after a lapse of 8, 12, 16 or 24 hours following feeding on the test diet. The procedure described by KUTHIALA (1983) was followed for the sterol extraction and the estimation of ^{3}H and ^{14}C content of the sterols.

RESULT

The results of the experiments in which the larvae were fed on a diet containing ^{14}C-cholesterol and ^{3}H-sitosterol in varying proportions are presented in Table 1. Eight hours after feeding 50.1 per cent of the cholesterol was recovered in the insect body when the proportion of cholesterol was double than that of sitosterol in the diet. With the increase in time to 24 hours the recovery of cholesterol in the insect body showed a reduction from 50.1 to 33.4 per cent. Even when the proportion of cholesterol was equal or one tenth of sitosterol, almost similar results were obtained. The recovery of sitosterol from the insect body was slightly lesss than that of cholesterol wherby after 8 hours it varied from 44.6 to 36 per cent as the proportion of sitosterol varied from one half to ten times as compared to cholesterol. Further, as the time interval after feeding increased there was a reduction in the sitosterol uptake by *Spodoptera* larva. At 50 per cent concentration of sitosterol as compared to cholesterol, the recovery of sitosterol in the insect was 44.6 per cent at 8 hours which declined to 18.2 per cent at 24 hours. Similar results were obtained at the other two concentrations tested (Table 1).

Similar studies with stigmasterol and cholesterol showed that about 50 per cent

TABLE 1. Per cent recovery of ^{14}C and ^{3}H from the larvae of *S. litura* given a test diet containing ^{14}C-cholesterol and ^{3}H-sitosterol in varying proportions.

Time after feeding in hours	cholesterol : sitosterol					
	0.01% + 0.005%		0.01% + 0.01%		0.01% + 0.1%	
	^{14}C	^{3}H	^{14}C	^{3}H	^{14}C	^{3}H
8	50.1 ± 2.53	44.6 ± 1.32	55.0 ± 5.33	47.6 ± 8.42	55.9 ± 9.84	36.0 ± 3.24
12	40.6 ± 1.82	23.4 ± 0.80	49.0 ± 3.95	44.5 ± 1.65	44.6 ± 7.13	36.9 ± 4.04
16	36.9 ± 1.85	19.3 ± 1.54	41.8 ± 5.37	31.8 ± 5.49	36.0 ± 5.25	28.6 ± 7.11
24	33.4 ± 2.76	18.2 ± 1.23	36.2 ± 4.94	12.6 ± 3.24	30.0 ± 1.45	15.2 ± 1.66

TABLE 2. Per cent recovery of ^{14}C and ^{3}H from the larvae of *S. litura* given a test diet containing ^{14}C-cholesterol and ^{3}H-stigmasterol in varying proportions.

Time after feeding in hours	cholesterol : stigmasterol					
	0.01% + 0.005%		0.01% + 0.01%		0.01% + 0.1%	
	^{14}C	^{3}H	^{14}C	^{3}H	^{14}C	^{3}H
8	48.1 ± 2.62	20.9 ± 0.83	54.8 ± 5.89	25.3 ± 4.28	50.8 ± 4.89	13.9 ± 2.95
12	44.3 ± 7.39	9.6 ± 1.47	54.6 ± 2.53	16.3 ± 1.83	47.3 ± 8.10	10.8 ± 2.34
16	33.6 ± 4.87	4.1 ± 0.81	30.3 ± 5.05	7.0 ± 1.80	29.5 ± 3.78	8.4 ± 1.39
24	13.6 ± 0.12	2.9 ± 0.18	10.3 ± 1.30	1.7 ± 0.25	9.7 ± 4.34	2.5 ± 0.33

cholesterol was taken up by the insect 8 hours after feeding irrespective of the proportion of cholesterol (Table 2). Again, an increase in time showed a reduced recovery of cholesterol which decreased to about 10 per cent 24 hours after feeding. The per cent recovery of stigmasterol 8 hours after feeding was 20.9 when its concentration was one half than that of cholesterol. A change in its proportion with respect to stigmasterol did not seem to change stigmasterol recovery much. With time the recovery of stigmasterol from the insect body showed a decline from 20.9 to 2.9 per cent 24 hours later when its concentration in the diet was one half as compared to cholesterol. Even an increase in the proportion of stigmasterol in the diet did not alter the per cent recovery of stigmasterol from the insect body. Table 3 shows the relative per cent incorporation of $^{14}[C]$ and $^{3}[H]$ in larval body of *S. litura* when fed simultaneously with equimolar concentrations of ^{14}C-cholesterol and ^{3}H-campesterol. The per cent recovery of cholesterol was slightly more than that of campesterol at all the time intervals tested. Cholesterol accounted for 49.4 per cent in the larval body after 8 hours of feeding which declined to 23.2 per cent 24 hours after feeding. Campesterol accounted for only 28.1 per cent 8 hours after feeding. The incorporation of campesterol also decreased with the increase in the time interval so much so that 24 hours after feeding campesterol accounted for only 16.9 per cent.

DISCUSSION

The absorption of dietary cholesterol and three common phytosterols namely, sitosterol, stigmasterol and campesterol by the larvae of *Spodoptera litura* was studied. The test diet contained two sterols simultaneously of which one was ^{14}C-cholesteral and the other was either ^{3}H-sitosterol or ^{3}H-stigmasterol or ^{3}H-campesterol. When sitosterol was added in different proportions to the diet along with cholesterol, in *S. litura* the absorption of cholesterol was more than that of sitosterol at all the concentrations tested. With the increase in time interval, although the absorption of individual sterols decreased in the insect body, the relative per cent absorption of cholesterol was more than that of sitosterol in all the cases. The change in the proportion of sitosterol as compared to cholesterol from one half to ultimately 10 times did not seem to affect the absorption of either of the sterols.

When stigmasterol was added to the diet of *S. litura* along with cholesterol both stigmasterol and cholesterol were absorbed by the insect body. The absorption of stigmasterol was less than that of cholesterol irrespective of the concentration used and the time interval. However, the maximum absorption of the two sterols was obtained only at 8 hours after feeding. In this case also an increase in the concentration of stigmasterol compared to cholesterol did not have any effect on the absorption of either of the sterols. When campesterol was added to the diet along with cholesterol both of the sterols were absorbed by *S. litura*. However, at all the time intervals tested the proportion of campesterol absorbed was always less as compared to cholesterol.

If the data from the tables 1 to 3 is recalculated for equimolar concentrations of the sterols tested in order to obtain the relative absorption of each sterol by *S. litura* in relation to cholesterol being considered as 100, the data obtained is shown in Table 4. It is observed that the absorption of cholesterol was maxmum in all cases. The relative per cent incorporation of sitosterol at 8 hours was 86.5 per cent followed by campesterol (56.9%) and stigmasterol (46.2%). The incorporation of sitosterol and stigmasterol declined with the increase in time interval. However, incorporation of campesterol increased as the time interval varied from 8 to 24 hours.

It has already been shown that sitosterol and stigmasterol constitute the major dietary sterols of *S. litura* whereas the bulk of the sterols found in the insect body is cholesterol (KUTHIALA, 1983). These results were partly due to the dealkylation of sitosterol and stigmasterol to cholesterol. A preferential uptake of cholesterol as compared to sitosterol was indicated by a higher incorporation of cholesterol in the haemolymph and the fat body (KUTHIALA, 1983). A preferential absorption of cholesterol as compared to sitosterol and stigmasterol in case of *S. litura* may also be indicated by the fact that about 10 times more of sitosterol and stigmasterol are required in the artificial diet for a growth similar to that on a cholesterol diet (SAXENA, 1984).

TABLE 3. Per cent recovery of ^{14}C and ^{3}H from the larvae of S. *litura* given a test diet containing ^{14}C-cholesterol and ^{3}H-campesterol.

Time after feeding in hours	cholesterol : campesterol	
	0.01% : 0.01%	
	^{14}C	^{3}H
8	49.4 ± 3.34	28.1 ± 3.81
12	27.2 ± 1.98	24.5 ± 1.09
16	11.0 ± 3.11	6.9 ± 2.32
24	23.2 ± 3.58	16.9 ± 1.10

Studies on sterol absorption have consistently indicated that plant sterols are absorbed to a lesser extent than cholesterol. In *Eurycotis floridana*, sitosterol, -Δ^4-cholestenol and epicholestanol are absorbed less effeciently than cholesterol (CLAYTON, 1964). A preferential absorption of cholesterol compared to many plant sterols has also been indicated in *Musca domestica* (MONROE *et al*, 1967, 1968). *Trogoderma granarium* also tends to selectively accumulate cholesterol and campesterol from the diet (SVOBODA *et al*, 1979). Similar studies in rats have shown that when either ^{14}[C]-cholesterol or ^{14}[C]-epicholesterol was administered into the rat, twice as much cholesterol was absorbed as compared to epicholesterol although the two differed only in the stereo-configuration of the

TABLE 4. Relative per cent incorporation of ^{14}C-cholesterol, ^{3}H-sitosterol, ^{3}H-stigmasterol and ^{3}H-campesterol in the larvae of *S. litura* when added to the diet in equimolar concentrations*.

Time after feeding	cholesterol : sitosterol : campesterol : stigmasterol			
	^{14}C-cholesterol	^{3}H-sitosterol	^{3}H-campesterol	^{3}H-stigmasterol
8	100	86.5	56.9	46.2
12	100	70.4	90.1	29.9
16	100	76.1	62.7	23.1
24	100	34.8	72.8	16.5

* Percentages calculated from the data on feeding experiments involving two labelled sterols at one time in the diet (Tables 1, 2 and 3.)

hydroxy group at third carbon (HERNANDEZ *et al.*, 1954). Sitosterol is absorbed less efficiently than cholesterol (GOULD & COOK, 1958). The simultaneous feeding of sitosterol and cholesterol did not reduce the absorption of cholesterol and its transport in the lymph of rats (SYLVEN & BORGSTROM, 1969). Further, it has been suggested that the selective accumulation of cholesterol by the intestinal mucosa of mammals is due to its affinity for a lipoprotein in the epithelial cells (GLOVER & MORTON, 1958; BORGSTROM, 1974). In *Ascaris* the block of the movement of sitosterol was associated with its entry into the epithelial cells (BEAMES *et al.*, 1974).

In *S. litura* the maximum absorption of all the four sterols was at 8 hours after feeding on the diet containing radiolabelled sterols. In rats also the maximum absorption of each sterol is seen between 4 to 8 hours and the per cent incorporation of stigmasterol and sitosterol was much less as compared to cholesterol (VAHOUNY *et al*, 1980). The concentration of each sterol in the sterol mixture administered appears to have very little effect on the per cent absorption of sterols as has been observed in case of *Spodoptera* in the present study.

It has been suggested that binding to certain lipoproteins may be involved in the absorption of cholesterol (CHINO & GILBERT, 1971). SINGHAL (1985) has indicated that the haemolymph lipoproteins of *P. americana* have a high affinity and low capacity for cholesterol whereas they have a low affinity and high capacity for sitosterol and stigmasterol. It is therefore, possible that the selectivity in the absorption of sterols observed in *S. litura* and also indicated in certain other insects may perhaps be due to differences in the binding of sterols to the transport lipoproteins. However, clear cut evidence for this suggestion remains to be obtained as yet.

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INVESTIGATIONS ON THE NUCLEAR POLYHEDROSIS VIRUS OF *DIACRISIA OBLIQUA* (WALKER) : BIOASSAY OF VIRAL ACTIVITY

G. S. BATTU[1] & N. RAMAKRISHNAN

Division of Entomology, Indian Agricultural Research Institute, New Delhi, India 110012

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Dosage-mortality data were obtained by leaf-dip method for 6, 9 and 11-day old larvae of *Diacrisia obliqua* Walker to a nuclear polyhedrosis virus. In the 3 age-group larvae, mortality was directly related to number of PIB administered orally. The calculated LC_{50} values in terms of polyhedral inclusion bodies (PIB) for 6, 9 and 11-day old larvae were 0.00743, 0.3212 and 0.5802 $\times$ 10^7 PIB per ml respectively. There was an inverse relationship between the fed virus concentrations and the time taken for 50 or 95 per cent mortality irrespective of the age-group tested.

(*Key words:* nuclear polyhedrosis virus, polyhedral inclusion body)

INTRODUCTION

The Bihar hairy caterpillar, *Diacrisia obliqua* (Walker) is a sporadic yet potentially destructive insect causing economic damage to a wide variety of plant species *viz.*, castor, cotton, cauliflower, jute, sesame, *urd*, *moong*, lobia, sweet-potato, soybean, sunflower, pea, etc. (PRUTHI, 1969; DESHMUKH *et al.*, 1979). A nuclear polyhedrosis virus (NPV) has been found to be an important key mortality factor for the natural control of this pest throughout Northern India (BATTU, 1982; BATTU & RAMAKRISHNAN, 1985). Quantitative observations on virus dose and host mortality are necessary for the production of the virus in the laboratory, as well as for its successful use as a biological control agent in the field. The LD_{50} values of this virus against 4 and 8 day old *D. obliqua* larvae were estimated as 741 and 13360 polyhedral inclusion bodies (PIB) respectively (RAMAKRISHNAN & CHAUDHARY, 1979). The present contribution deals with activity of nuclear polyhedrosis virus on 6, 9 and 11-day old larvae of *D. obliqua*.

MATERIAL AND METHODS

The polyhedral inclusion bodies of the NPV of *D. obliqua* were extracted from dead, final instar larvae of *D. obliqua* by differential centrifugation and the final concentration was characterised as number of PIB per ml through haemocytometer. From the stock suspension serial dilutions were made for the purpose of bioassay studies.

Virus inclusion bodies were administered to field collected 6, 9 and 11-day old larvae of *D. obliqua* through the leaf-dip method. A pinch of methyl cellulose was used as a sticker. The larvae were fed in groups of 10 in a small jar for 24 h on the treated castor leaves and subsequently reared on clean fresh castor leaves. Each serial dilution was tested by treating a total of 50 larvae in five replicates for each of the age

[1] Present address: Insect Pathologist, Department of Entomology, Punjab Agricultural University, Ludhiana - 141004; Part of the Ph. D. thesis of the Senior Author approved by the P. G. School, Indian Agricultural Research Institute, New Delhi.

groups of the test larvae. Separate control larvae fed with castor leaves treated with distilled water only, were also maintained to detect any natural mortality, under similar conditions. The mortality data were recorded daily. The mortality data obtained were probit-analysed (FINNEY, 1977). The lethal time for 50 and 95 per cent mortality (LT_{50} and LT_{95}) were calculated according to BIEVER & HOSTETTER (1971).

RESULTS AND DISCUSSION

The results o bioassay studies with nuclear polyhedrosis virus on *D. obliqua* are presented in Table 1 and dosage mortality lines in Fig. 1.

In the three age group larvae tested, mortality was directly related to the number of PIB administered orally to *D. obliqua*. The LC_{50} values for 6, 9 and 11-day old larvae were 0.00743, 0.3212 and 0.5802×10^7 PIB per ml respectively. The respective slope values were 0.1674, 0.4078 and 0.1815. The slope values of the dosage-mortality curve indicate the degree of variability in the insect population tested. The lower the slope value greater is the variability. Normally, the slope values are very low in bioassay studies, with insect pathogens (BUCHER, 1958; BURGES & THOMPSON, 1971),

RAMAKRISHNAN & CHAUDHARY (1979) reported 741 and 13360 PIB as LD_{50} values for 4 and 8-day old larvae of *D. obliqua* having respective average weight of 11.6 and 119.6 mg. They have also indicated the lower slope values of 0.503 and 0.443 for 4 and 6-day old larvae respectively. MARTIGNONI (1957) and MARTIGNONI & SCHMID (1961) reported the lowest slope values of 0.46 and 0.77 respectively for *Eucosoma griseana* (Hubn.) and *Phryganidia californica* Packard, for a granulosis and a nuclear polyhedrosis virus. According to them, the low slope value was found in insect population which is in the pre-epizootic phase and the value generally increased when once insect population was exposed to pathogens. It is worth-pointing out at this juncture that the nuclear polyhedrosis virus was found almost continuously associated with *D. obliqua* under field conditions (BATTU, 1982; BATTU & RAMAKRISHNAN, 1985). It is, therefore, likely that the insect population used in the present experiments might be in the pre-epizootic phase.

On the basis of LC_{50} values, it can be stated that 6-day old larvae of *D. obliqua* were most susceptible among the age group tested. The relative susceptibility indices were 78.1 and 1.81 for 6 and 9-day old larvae respectively compared to 11-day old

TABLE 1. Dosage-mortality data for the different age group of larvae of *D. obliqua* fed with nuclear polyhedrosis virsus.

Age of the larvae (days)	Regression equation	LC_{50} values (PIB/ml $\times 10^7$)	Relative susceptibility ratio	Fiducial limits
6	$Y = 4.1846 + 0.1674\ X$	0.00743	78.1	0.0006622—0.07078
9	$Y = 2.3465 + 0.4078\ X$	0.32120	1.81	0.09513 —1.085
11	$Y = 3.7724 + 0.1815\ X$	0.58020	1.00	0.05081**—6.401**

** These data were found to be heterogenus at $P = 0.05$ The heterogeneity formula was used to used to calculate the fiducial limits.

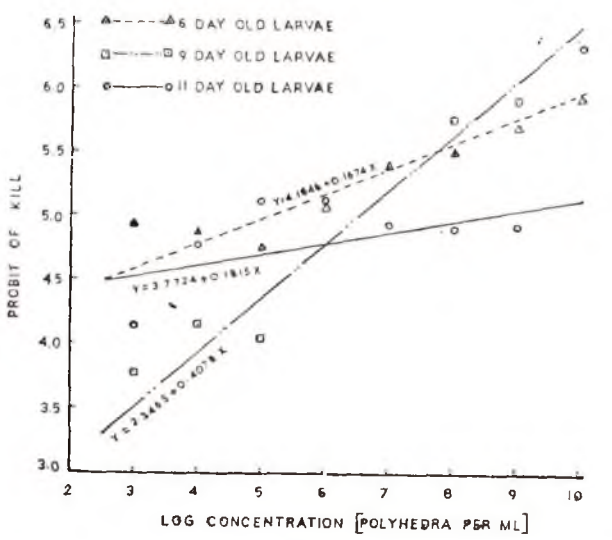

Fig. 1: Log concentration probit kill regression lines of different age-group larvae of *D. obliqua*

larvae. Similar quantitative differences in LD_{50} values was observed between different age groups in *Malacosoma disstria* Hubn. (STAIRS, 1965), *Spodoptera litura* (Fabr.) (KOMOLPITH & RAMAKRISHNAN, 1975; PAWAR & RAMAKRISHNAN, 1976), *Heliothis zea* Boddie and *Heliothis virescens* (Fabr.) (IGNOFFO, 1966).

The LT_{50} and LT_{95} values for fed-virus concentrations (Table 2) also revealed that as the test-virus concentration fed increased, there was a corresponding decrease in the LT_{50} values. The concentration of 10^5 PIB/ml with reference to 6-day old larvae however, resulted in the highest LT_{50} value of 233.06 which cannot be explained rationally. This inverse relationship between the fed-virus concentration and the time taken for the required per cent larval mortality existed irreepective of

TABLE 2. LT_{50} and LT_{95} values of different age-group larvae fed at various concentrations of PIB ml.

Virus concentration fed* (PIB/ml)	LT_{50} values (h)			LT_{95} values (h)		
	6-day old	9 day old	11 day old	6 day old	9 day old	11 day old
10^3	196.51	264.00	220.50	309.17	319.24	329.40
10^4	194.67	252.05	213.02	317.65	311.55	303.20
10^5	233.06	236.40	187.23	311.11	327.60	255.00
10^6	185.37	237.13	187.23	305.10	326.00	261.08
10^7	163.62	237.43	195.60	287.11	209.08	250.51
10^8	163.04	156.39	195.00	225.54	210.48	239.41
10^9	164.08	159.00	194.00	238.54	209.10	231.00
10^{10}	148.09	165.29	170.75	225.91	212.05	202.51

* By leaf-dip method.

the age-group tested. This kind of dose dependency is well documented among various nuclear polyhedrosis of insects (AIZAWA, 1963; BERGOLD, 1963; STEINHAUS, 1949; CHAUDHARY, 1979). From the LT_{50} values, it is seen that the polyhedrosis disease has an incubation period of 6 to 7 days at the highest tested concentration of 10^{10} PIB/ml. As the virus infected larvae continue to feed till death, it would be better to use moderately higher concentration which has a low LT_{50} value under field condition.

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FIRST RECORD OF *LIRIOMYZA COMPOSITELLA* SPENCER AND *L. BRASSICAE* (RILEY) (DIPTERA : AGROMYZIDAE) AS PESTS OF ORNAMENTAL CROPS IN SOUTH INDIA

SUJAYA UDAYAGIRI

Indian Institute of Horticultural Research, Hessaraghatta, Bangalore, India 560 089

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Liriomyza compositella Spencer was observed feeding on the leaves of China Aster and *Zinnia* while *L. brassicae* (Riley) attacked the leaves of garden nasturtium. This is the first record of *L. compositella* from South India. *L. brassicae* is reported from this region, but only as a pest of cabbage. Significant damage, caused by the miners, was observed on China Aster and nasturtium.

(Key words: Agromyzids, *Liriomyza compositella, L. brassicae,* first record, ornamental crop pests, S. India)

The leaf-miners *Liriomyza compositella* Spencer and *L. brassicae* (Riley) have been observed infesting ornamental plants in Northern, Western and Central India. SPENCER (1961) bred *L. compositella* from the leaves of goldenrod, *Solidago canadensis* Linn., at Bombay, while garden nasturtium is reported as the host of *L. brassicae* from Ferozepur (Punjab), Ranchi (Bihar) (SEHGAL & TREHAN, 1963); Agra (Uttar Pradesh) (BERI, 1974) and Damoh (Madhya Pradesh) (GOKULPURE, 1975). GOKULPURE (1975) also reported the ornamental plants *Dahlia variabilis* Desf., *Reseda odorata* L. and *Verbena phlogiflora* Cham. as hosts of *L. brassicae*.

There is no report from Southern India of any *Liriomyza* species feeding on an ornamental plant. The only species reported from this region is *L. brassicae* which has been observed feeding on cabbage (NAGARKATTI & JAYANTH, 1982).

Contribntion No. 114/85 of Indian Institute of Horticultural Research, Hessaraghatta.

Ornamental plants were raised without insecticidal treatment at the Experimental Farm of the Indian Institute of Horticultural Research at Hessaraghatta, located 26 km north of the city of Bangalore, in 1984 and 1985, to study the damage caused by various insect pests including leaf-miners. In July 1985 commercial cultivations of ornamental crops at Shivakote, 2.5 km from Hessaraghatta, were surveyed to study insect pest attack. The infested plant parts were collected and kept in plastic jars (13 cm × 10 cm) with moist cotton swabs (to maintain their freshness) till adult emergence. The identities of the miners were established by Dr. K. A. Spencer, the Agromyzidae specialist at Cornwall, U. K.

Liriomyza compositella Spencer

This miner is reported here for the first time from Southern India. It was observed feeding on two ornamental plants.

1. Callistephus chinensis Nees

(Family: Asteraceae common name: China Aster)

Infestation on China Aster was observed on the following occasion:—

(i) On China Aster raised at the Experimental Farm at Hessaraghatta, between January and May 1984, infestation by the miner which was first observed on 31 March, continued till May when the plants dried.

(ii) Leaf-miner infestation was detected in six-week old plants of China Aster grown between January and May 1985 in 75 pots in an open field at Hessaraghatta. Infestation was observed from 8 February onwards.

(iii) Damage by the miner was observed on 18 July 1985 during the field survey at Shivakote where China Aster was being raised for commercial purposes.

Damage: The larvae mined the leaves and occasionally the sepals. The mines, formed on the upper surfaces of the leaves, were white, turning brown when dry. These were irregularly linear, occasionally coalescing to form a blotch. Black frass was deposited in more or less continuous threads in the channel. There were, at times, more than one mine on a leaf. (In February 1985, 35% of the infested leaves contained two mines per leaf). The larvae left the mines to pupate in the soil.

In 1984, 10% damage to China Aster plants was recorded at Hessaraghatta. In each plant, the damage ranged from 2% to 42%. Damage to the sepals was less than 5%. In the potted plants raised in 1985, 17% damage was recorded in the young plants. The damage ranged from 0 to 60% per plant. At Shivakote, in July 1985, 20% damage was observed. The damage ranged from 0 to 40% per plant.

2. Zinnia elegans Jacq.

(Family: Asteraceae: common name: *Zinnia)*

Zinnia was raised in a bed 20 m × 1m, at Hessaraghatta, between January and June 1985. The plants were located in an open field.

Infestation by this miner was observed in April 1985. When examined in May and June, the plants did not appear to contain any infestation.

Damage: In *Zinnia*, only the leaves were found to be affected. The damage was similar to that described above on China Aster. However, infestation was very low ($\angle$ 5%).

L. compositella is not reported earlier from Southern India. It is reported from Bombay (SPENCER, 1961) and from Delhi (SPENCER, 1966). It is also recorded from Sri Lanka and Formosa (SPENCER, 1961).

In India the miner has been bred from leaves of a single ornamental plant namely goldenrod, *Solidago canadensis* Linn., (SPENCER, 1961) and from the weed *Xanthium strumarium* Linn. (SPENCER, 1966). Host plants from other countries include the composite *Gynura lycopersicifolia* D. C. and *Tithonia diversifolia* A. Gray (SPENCER, 1961). But nowhere is *L. compositella* reported as being of economic importance.

At Hessaraghatta and Shivakote *L. compositella* was observed as a pest on China Aster. Heavy infestation by this pest greatly reduces the market value of this ornamental crop which is in great demand as cut flowers in Bangalore and in the rest of the State of Karnataka. In 1983–1984, 47.6 hectares were under China Aster cultivation in Bangalore alone

(ANON, 1985). There has been no earlier study on the pests of this crop which is, perhaps, why *L. compositella* attack on China Aster has not been reported earlier. It is likely that *L. compositella* will become a potential pest of this ornamental crop at Bangalore and in the surrounding regions.

The low level of infestation on *Zinnia* suggests that it is not a preferred host.

L. brassicae (Riley)

This miner, reported here for the first time from Southern India, was collected from a single ornamental host *Tropaeolum majus* Linn.

(Family: Tropaeolaceae: common name: garden nasturtium)

Garden nasturtium raised at Hessaraghatta for the first time, between November 1984 and March 1985, was attacked by *L. brassicae*. Infestation, first observed in December 1984, continued till March when, due to drying, the plants were uprooted.

Damage: The larvae mined the leaves on the upper or lower surface. The mines were narrow, linear, white or pale green with black frass visible as more or less connected threads. There were usually more than one mine on a leaf. When fully grown, the larva left the mine and pupation occurred in the soil.

Excess of 20% leaf damage was observed in garden nasturtium.

L. brassicae a pest of cruciferous plants, is cosmopolitan. In India, it is reported from New Delhi (SPENCER, 1961); Punjab, Bihar (SEHGAL & TREHAN, 1963); Uttar Pradesh, Rajasthan (BERI, 1971); Madhya Pradesh (GOKULPURE, 1975) and Karnataka (NAGARKATTI & JAYANTH, 1982).

L. brassicae is a common pest on *Tropaeolum* due to the presence of the mustard oil glycosid myrosin which is one of the attractants determining the females' choice of host (SPENCER, 1973). In India, it is reported on the common climbing species, *T. majus* Linn., from Northern India. This was first recorded by SEHGAL and TREHAN (1963). BERI (1971) described the immature stages of *L. brassicae* and studied its biology on *T. majus* at Agra (BERI, 1974). The miner was later reported on the dwarf species, *T. minus* Linn., from Central India (GOKULPURE, 1975). Though *L. brassicae* is reported from Southern India (NAGARKATTI & JAYANTH, 1982), it is only recorded on cabbage. Nasturtium is not commonly grown in South India and this may be the reason why its association with *L. bracsicae* has not been reported earlier from this region. At Hessaraghatta, however, damage by the miner was significant. If cultivation of nasturtium increases at Bangalore, *L. brassicae* is likely to be a major pest of this plant.

BERI (1974) reported that plants under shade show very little infestation. However, at Hessaraghatta, infestation was high on nasturtium plants raised partly in the shade.

L. brassicae is reported on *Dahlia variabilis* Desf. (Asteraceae), *Reseda odorata* Linn. (Resedaceae) and *Verbena phlogiflora* Cham. (Verbenaceae) from Central India (GOKULPURE, 1975). However, at Bangalore it was not observed on any other ornamental plant.

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NEW SPECIES AND RECORDS OF TETRANYCHID MITES (TETRANYCHIDAE : ACARINA) FROM INDIA

P. KARUPPUCHAMY & M. MOHANASUNDARAM

Department of Agricultural Entomology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore, India 641 003

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The paper presents the descriptions of two new species of tetranychid mites viz, *Tylonychus jayaraji* spec. nov. and *Oligonychus ponmanaiensis* spec. nov. and the new host records for *Tetranychus ludeni* Zacher, *Schizotetranychus spiculus* Baker and Pritchard and *Eutetranychus orientalis* (Klein) from India.

(Key words: new tetranychids, mites, *Tylonychus jayaraji, Oligonychus ponmanaiensis, Tetranychus ludeni, Schizotetranychus spiculus, Eutetranychus orientalis)*

In the course of survey and study of phytophagous mites, two species of tetranychid mites were found new to science. These species are adequately sketched and described. The holotype and paratype slides were deposited in the Department of Agricultural Entomology Collections, Tamil Nadu Agricultural University, Coimbatore-641003, India. All measurements are in μm.

The records of three known species on new hosts are also given.

1. Tylonychus jayaraji spec. nov. (Fig. 1)

This species resembles *T. tasmaniensis* (Miller, 1966) and *T. transvaalensis* (Mayer, 1974), but can be differentiated from the above two species by the absence of dorsal tubercles and the members of fourth pairs of dorsocentrals which are located further apart than the third pair alone. It is differentiated from *T. tasmaniensis* by very short anterior and long posterior projection of aedeagus and from *T. transvaalensis* by the elongate gnathosoma.

To accommodate all the above three species in this genus, *Tylonychus* is redescribed as follows: The dorsal integument bears numerous irregularly shaped spinules. The body setae are stout, serrate and borne on tubercles or tubercles may be absent. The members of fourth pair of dorsocentral hysterosomals are located further apart than those of the other three pairs of dorsocentrals or third pair alone.

Female: (Fig. 1 A)

Body including gnathosoma 575 long (475—600) and excluding gnathosoma is 375 long (310—420) and the breadth is 255 (220—260). The length of the leg I is 265; leg II 202; leg III 210 and leg IV 240.

Dorsum: The dorsum consists of 13 pairs of serrate setae (Fig. 1 D) which are shorter than the distances between the bases of consecutive setae. The setae are broad at the base and narrow at the tip. The propodosoma possesses reticulate pattern of striae. The dorsal integument consists of strong tranverse striae between

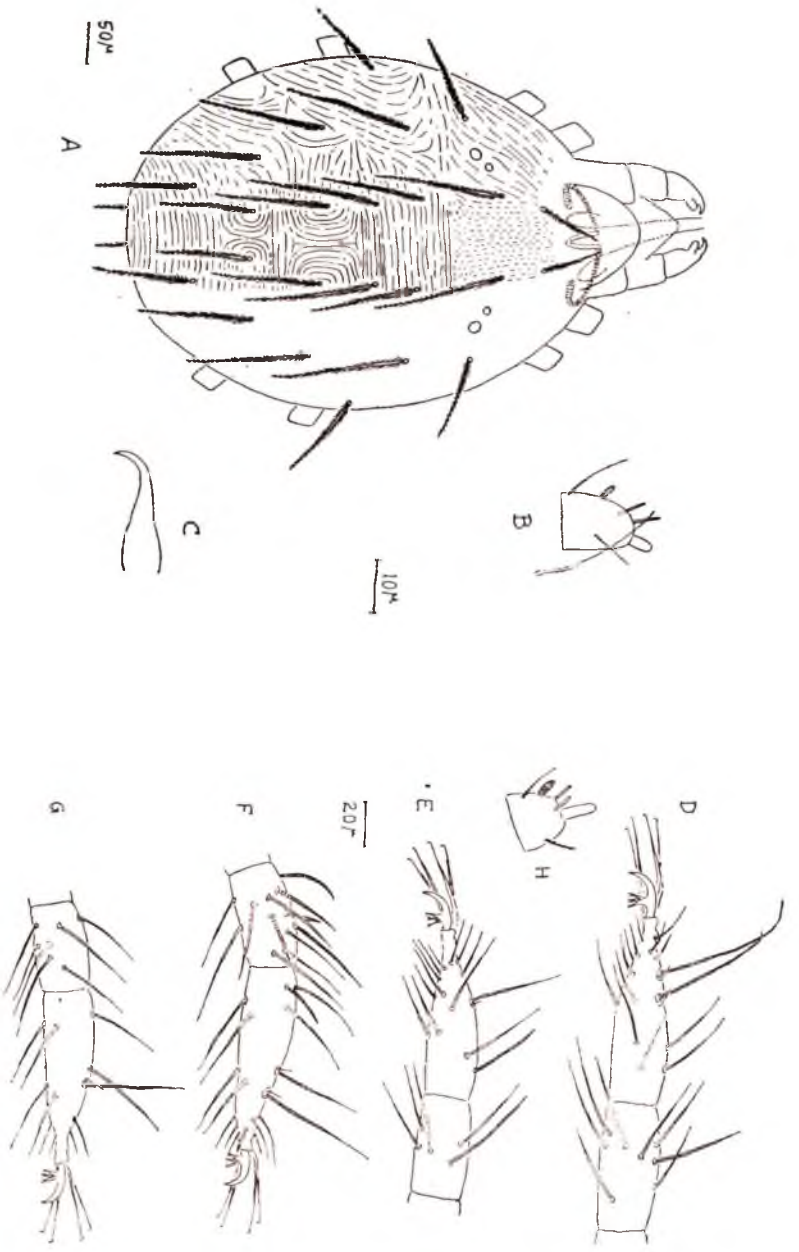

Fig. 1. *Tylonychus jayaraji* sp. nov.

A. Dorsal view of female; B. Palp tarsus of female; C. Dorsal pattern of female; D. Dorsal seta; E. Aedeagus; F. Tibia and tarsus I of female; G. Tibia and tarsus II of female; H. Tibia and tarsus I of male; I. Tibia and tarsus II of male.

dorsocentrals and between dorsocentrals and dorsolaterals and longitudinal striae in the marginal area. The transverse striae possess variously shaped spinules (Fig 1 C).

Gnathosoma: The gnathosoma is long and curved downwards. The peritreme ends in a sac-like structure. The terminal sensillum is long and is four times as long as broad (Fig. 1 B).

Venter: The venter possesses triangular striae just anterior too genital area and anterior to this area possesses transverse striae.

Legs: The chaetotaxy of legs is as follows: (Tibia and tarsus I and II-Fig. 1 F and 1 G)

Coxa: 2-2-1-1; Trochanter: 1-1-1-1; Femur: 7-7-4-4;

Genu: 5-5-3-3; Tibia: 9-7-7-6; Tarsus: 11+2 dup -9+1 dup-7-7.

The duplex setae are distal and approximate. The dorsal leg setae are serrate and stout whereas the ventral leg setae are setaceous, empodium ends in a single claw without proximoventral hairs.

Male: Body including gnathosoma is 455 long and excluding gnathosoma is 310 long and the breadth is 205. The dorsal striae are smooth without spinules. The propodosomal striae are longitudinal and hysterosomal striae are transverse. The gnathosoma is long and peritreme ends in a sac like structure as in the female. The terminal sensillum in the palp tarsus is rudimentary. The length of leg I is 330; leg II 225; leg III 250 and leg IV 265. The chaetotaxy of legs is as follows: Coxa: 2-2-1-1; Trochanter: 1-1-1-1; Femur: 7-5-4-4; Genu: 5-5-3-3; Tibia: 13-7-7-6; Tarsus: 13+2 dup -9+1 dup-7-7 (Tibia and tarusus I and II-Fig. 1 H and 1 I).

Aedeagus: The aedeagus bends dorsad and ends in a knob, the anterior projection is small and the posterior projection is very long (Fig. 1 E).

Field recognition: The mites are brown in colour and found on the upper surface of leaves.

Types: A holotype slide with ♀♀ and ♂ and six paratype slides with ♀♀ and ♂♂ INDIA: Varanasi 2.vi.1985 ex *Tamarix* sp. (Tamaricaceae) Coll. M. Mohanasundaram (No. 64 TNAU).

Key to the species of Tylonychus

1. Gnathosoma excessively elongate and curved slightly downwards Gnathosoma of normal length; aedeagus with an anterior and posterior projection in the distal part.

T. transvaalensis Meyer (1974)

2. Distal part of aedeagus tapering evenly; the dorsal body setae borne on tubercles.

T. tasmaniensis Miller (1966)

Aedeagus with a very short anterior and a long posterior projection in the knob; the dorsal body setae without tubercles.

T. jayaraji spec. nov.

T. jayaraji spec. nov. is named in honour of Dr. S. Jayaraj, Director, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore in appreciation of his interest in the development of Plant Protection and encouragement given for the study of mites.

2. Oligonychus ponmanaiensis sp. nov. (Fig. 2)

This species resembles *O. paruvianus* (Mc Gregor, 1956) and *O. platani* Mc Gregor, 1956). However it can be differentiated from the former by very long dorsal hysterosomal setae and sharply pointed ventrally directed aedeagus and

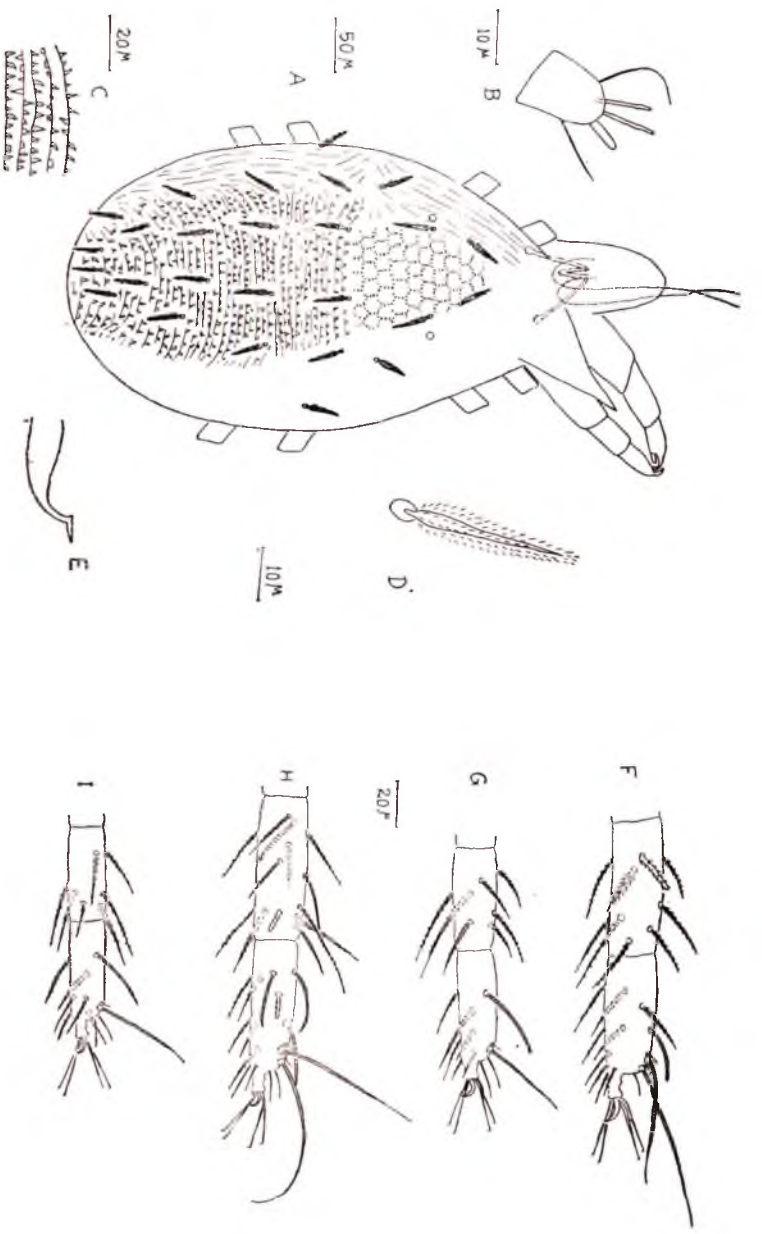

Fig. 2. *Oligonychus ponmanaiensis* sp. nov.

A. Dorsal view of female; B. Palp tarsus of female; C. Aedeagus; D. Tibia and tarsus I of female; E. Tibia and tarsus II of female; F. Tibia and tarsus I of male; G. Tibia and tarsus II of male; H. Palp tarsus of male.

from the latter by the short proximal duplex setae in tarsus I of male and female.

Female: Body including gnathosoma 505 long (505—555) and excluding gnathosoma 360 long (360—405) and breadth is 315 (315—350). The length of the leg I is 410; leg II 285; leg III 325 and leg IV 430.

Dorsum: (Fig 2 A):

The body consists of 13 pairs of very long serrate setae not borne on tubercles. The setae are longer than the distances between the bases of consecutive setae. The second pair of propodosomal setae, the first and second pair of dorso-central setae are longer than twice the distance between the consecutive setae i. e., for e. g., the tip of the first pair of dorso-central setae cross the base of the third pair of dorsocentrals. The dorsal lobes are triangular in shape. The propodosoma bears longitudinal striae and hysterosoma bears transverse striae except between third and fourth pair of dorso-centrals where the striae are longitudinal.

Gnathosoma: The terminal sensillum is two and half times as long as broad (Fig 2 B). The peritreme is hooked distally.

Venter: The ventral striae are transverse except longitudinal striae immediately anterior to genital area.

Legs: The setal formulae of legs (Tibia and Tarsus I and II Fig. 2 D and 2 E).

Coxa: 2–2–1–1; Trochanter: 1–1–1–1; Femur: 10–6–4–4;

Genu: 5–5–4–4; Tibia: 8–5–5–5; Tarsus: 13+2 dup–13+1 dup–11—11

Male: Body including gnathosoma 430 (405—505) long and excluding gnathosoma 310 (290—350) long and breadth is 220 (180—255).

Gnathosoma: The terminal sensillum of palp tarsus is three and half times as long as broad (Fig 2 H). The peritreme is hooked distally.

Legs: The chaetotaxy of legs: (Tibia and Tarsus I and II-Fig 2 F and 2 G)

Coxa: 2-2-1-1; Trochanter: 1-1-1-1; Femur: 8-6-4-4; Genu: 5-5-4-4; Tibia: 12-7-6-6; Tarsus: 13+2 dup-12+1 dup-12-12.

Four tactile setae are located well proximal to the duplex setae in tarsus I.

Aedeagus: The shaft of the aedeagus bends ventrad abruptly at right angle and tapers sharply (Fig 2 C).

Field recognition: This species is red in colour and found on the upper surface of leaves.

Types: A holotype slide with ♀♀ and ♂♂ and a paratype slide with ♀♀ and ♂♂ INDIA: TAMIL NADU: Ponmanai, 23.i.1985 ex. *Haevia braziliencis* (Rubber) Coll. P. Karuppuchamy (No. 51 TNAU).

Five paratype slides with ♀♀ and ♂♂ INDIA: TAMIL NADU: Coimbatore 8.iv.1985 Ex. *Bauhinia* sp. Coll. P. Karuppuchamy (No. 53 TNAU).

3. Tetranychus ludeni, Zacher, 1913

Collection data: Five slides with ♀♀ INDIA: TAMIL NADU: Coimbatore ex *Abelmosches esculentus* 20.vi.1984 Coll. P. Karuppuchamy (No. 3 TNAU).

Two slides with ♀♀ INDIA: TAMIL NADU: Oddanchatram ex. *Solanum melongena* 15 vii.1984 Coll. P. Karuppuchamy (No. 12 TNAU). Two slides with ♀♀ INDIA: TAMIL NADU: Coimbatore Ex. *Glycine max* 6.viii.1984 Coll. P. Karuppuchamy (No. 22 TNAU). Four slides with ♀♀ and ♂♂ Coimbatore Ex. *Cajanus*

cajan (Redgram) 27.x.1984. Coll. P. Karuppuchamy (No. 30 TNAU). Five slides with ♀♀ and ♂♂. Coimbatore Ex. *Desmodium tortosum* (Desmodium) 30.x. 1984 Coll. P. Karuppuchamy (No. 33 TNAU). All hosts except redgram are new host records for this mite.

4. Schizotetranychus spiculus (Baker and Pritchard, 1960)

Collection data: Three slides with ♀♀ and ♂♂ INDIA: TAMIL NADU: Neyveli ex. *Murraya koenigii* (curry leaf) (Rutaceae) 1.vii.1984 Coll. M. Mohanasundaram (No. 9 TNAU).

5. Eutetranychus orientalis (Klein, 1936)

Collection data: Three slides with ♀♀ and ♂♂ INDIA: TAMIL NADU: Coimbatore Ex. *Nerium odorum* Soland (Apocynaceae) 25.ix.1984. Coll. P. Karuppuchamy (No. 28 TNAU).

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PARASITOID – HOST RELATIONSHIP BETWEEN *TRIOXYS (BINODOXYS) INDICUS* SUBBA RAO & SHARMA (HYMENOPTERA : APHIDIIDAE) AND *APHIS CRACCIVORA* KOCH (HEMIPTERA : APHIDIDAE). : EFFECT OF HOST PLANTS ON THE SEX RATIO OF THE PARASITOID

ARVIND KUMAR & C. P. M. TRIPATHI

Laboratory of Entomology, Department of Zoology, University of Gorakhpur, Gorakhpur, India 273 009

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The aphid *Aphis craccivora* was reared on *Cajanus cajan, Dolichos lablab* and *Solanum melongena* and the effect of these host plants on the sex ratio of *Trioxys (Binodoxys) indicus* have been discussed which proved to be density dependent. The decrease in the sex ratio i .e., production of greater number of males than females, is maximum in case of *S. melongena* and minimum in *C. cajan* reared aphids. The texture of the leaf surfaces of the host plants have been attributed to influence the sex ratio. Results show that for obtaining maximum female progeny, fewer release of parasitoids at any release site will be better During the off season, *Dolichos lablab* (perennial plant) is suggested for the mass rearing of the parasitoid when the ideal host plant *C. cajan* is not available in the field.

(Key words: Trioxys indicus, Aphis craccivora, sex ratio, host plants, parasitoid-host relationship, *Dolichos lablab, Cajanus cajan, Solanum melongena*)

INTRODUCTION

The sex ratio of a parasitoid is of prime importance when the parasitoid is to be used in a biocontrol programme for the suppression of their hosts, as it is the female wasp which plays an effective role in parasitisation and mortality of the pest (WAAGE, 1982). *Trioxys (Binodoxys) indicus* Subba RAO & SHARMA is useful in the control of *Aphis craccivora* Koch, a serious pest of *Cajanus cajan* in India, causing serious economic loss to the farmers. In arrhenotokous aphidiids, information on the female biased sex ratio is available (SHIROTA *et al.*, 1983) but there is scanty information on the influence of host plants on the sex ratio. This prompted the authors to undertake the present work and also to determine alternative host plant(s) that can be used for the mass rearing of *T. indicus* when *C. cajan* is not available, so that the parasitoids are available in time for release to control the aphid, *A. craccivora* in the field.

MATERIALS AND METHODS

The aphid, *A. craccivora* and the parasitoid, *T. indicus* were reared in the laboratory at 18 ± 2°C and 75 ± 5% RH (SINHA & SINGH, 1980). To study the effect of various host plants reared aphids on the sex ratio of *T. indicus*, 12 petri dishes (15 cm diameter; numbered 1—12) were divided into 3 sets of 4 each. Zero to ten hours old, mated female parasitoids, satiated with a 30% honey solution and third instar nymphs of the aphids (the stage most preferred by the parasitoid) drawn

from a third generation laboratory culture (KUMAR *et al.*, 1983) were used in the experiments. One hundred aphids were placed separately on each of the equal sized (3 × 1.5cm) leaves of *Cajanus cajan*, *Dolichos lablab* and *Solanum melongena*. Thereafter, these leaves were kept individually in numbered petri dishes having moistened filter paper in the bottom. Petri dishes 1—4, 5—8, and 9—12 contained aphids reared on *C. cajan*, *D. lablab* and *S. melongena* respectively. One parasitoid was placed in petri dish 1, 5, and 9; two parasitoids were placed in petri dish 2, 6, and 10; 4 parasitoids were placed in petri dish 3, 7, and 11 and the other contained 8 parasitoids and were allowed to attack hosts for 15 minutes. The experiment was performed ten times. After parasitisation, the aphids were reared on their respective host plants using the technique of TRIPATHI & KUMAR (1984). On the day of mummification, the mummies were carefully picked off with fine camel hair brush and were transferred singly into marked sterilised glass vials (2.5×10 cm) with leaf cuttings of the host plants (to provide moisture to the developing eggs) until emergence. The mouth of the glass vials were kept plugged with absorbent cotton. On emergence, the parasitoids were counted, sexed and analysed statistically. The sex ratio was calculated as a proportion (in %) of females out of total emergents (MACKAUER, 1976). The mummies which did not yield a parasitoid were not considered.

RESULTS

Table 1 and Figure 1 show that as the parasitoid density increases the sex ratio decreases significantly at all parasitoid densities in all the tested host plants reared aphids. Further, this decrease has been found in a descending order from *C. cajan* ($Y = 84.132 - 0.797X$; $r = -0.967$; $P < 0.001$) through *D. lablab* ($Y = 77.833 - 1.352X$; $r = -0.965$; $P < 0.001$) to *S. melongena* ($Y = 72.147 - 1.330X$; $r = -0.885$; $P < 0.001$) reared aphids (Figure 1). The impact of host plants on the sex ratio of the parasitoid was further supported by analysis of variance ($F = 50.81$; $P < 0.001$). Parasitoid densities also significantly lower the sex ratio ($F = 11.46$; $P < 0.01$) (Table 2); t-test also points in this direction.

TABLE 1. Sex ratio (the proportion of females in the population = 100 × number of females/ total number of parasitoids) of the progeny of *T. indicus* in varying parasitoid densities put with 100 different host plants reared *A. craccivora*. Each entry is the mean of the replicates ±SD.

Initial no. of parasitoid	*C. cajan*	Significanee of mean difference 't-test'	*D. lablab*	significance of mean difference t'-test'	*S. melongena*
1	84.11 ± 3.26	t = 4.63 $P<0.001$	77.60 ± 3.02	t = 2.74 $P<0.025$	73.26 ± 4.00
2	81.98 ± 4.31	t = 3.90 $P<0.005$	74.73 ± 3.98	t = 3.02 $P<0.01$	68.07 ± 5.74
4	80.50 ± 4.37	t = 5.06 $P<0.001$	71.03 ± 2.46	t = 3.96 $P<0.005$	64.68 ± 4.42
8	78.11 ± 4.22	t = 4.64 $P<0.001$	67.67 ± 5.72	t = 2.31 $P<0.05$	62.63 ± 3.84

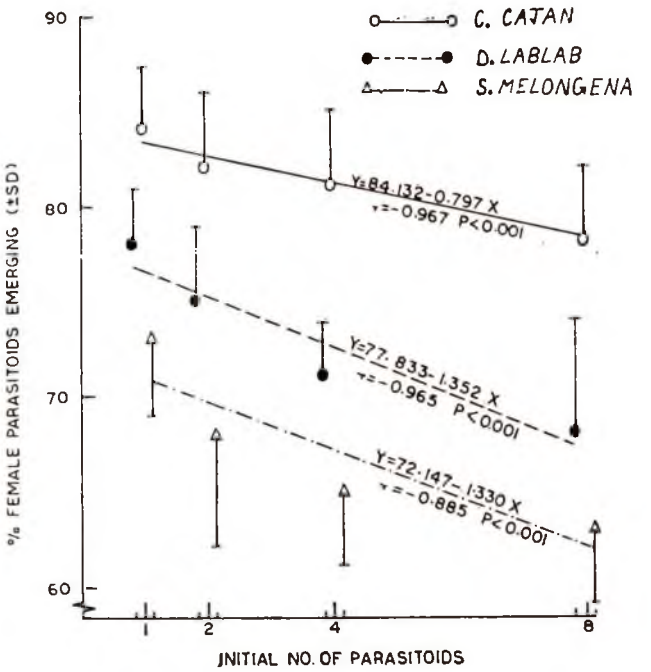

Fig. 1. Graphic representation of % female parasitoids emerging at different initial number of *T. indicus* put with 100 different host plants reared *A. craccivora* (mean ± SD).

TABLE 2. Summary of computation for analysis of variance of the data of Table 1.

Source of variation	d. f.	Sum of squares	Mean squares	F value	*P*
Between 3 host plants	2	385.15	192.57	50.81	0.001
Between 4 parasitoid density	3	130.28	43.43	11.46	0.01
Total interaction	6	22.74	3.79		
Total	11	538.17	48.92		

DISCUSSION

Table 1 and Figure 1 show that as the parasitoid density increases, the sex ratio decreases significantly in all the tested host plants reared aphids which supports the work of WYLIE (1971). It may be due to the lower mortality of male progeny in superparasitised hosts and a decrease in the proportion of diploid eggs laid, owing to physical and chemical interference phenomenon (VIKTOROV & KOCHETOVA, 1972). The sex ratio was very low

when the parasitoid density was increased to eight and this may have occurred due to strong mutual interference as indicated by a negative slope (KFIR & ROSEN, 1980; KUMAR & TRIPATHI, 1985).

As stated above (Table 2) the sex ratio decreases in the aphids reared on all the tested host plants. This decrease is minimum in *C. cajan* reared aphids, maximum in *S. melongena* reared aphids while *D. lablab* reared aphids occupy an intermediate position. It was suggested by RAMASESHIAH *et al.* (1968) that the host plants seem to affect the sex ratio. The present finding clearly shows that the host plants play a positive role in influencing the sex ratio of the parasitoid.

The volatile or contact chemicals of the host plant *(C. cajan)* attracts the parasitoid more (ELZEN *et al.*, 1984) to the vicinity of the host and thereby the parasitisation is affected with the result that the sex ratio is affected. These chemicals might be either in small quantity or somewhat different in nature due to which they do not have the same effect in the other two tested plants.

The leaf surface of *C. cajan, D. lablab* and *S. melongena* host plants are covered with hairs which are fine and soft in *C. cajan*, strong and stout in *D. lablab* and multibranched stellate in *S. melongena* (KUMAR *et al.*, 1983). The parasitoid in its movement on the leaf surface faces comparatively more difficulty in searching *D. lablab* and *S. melongena* leaves than in *C. cajan* leaves. This interference might result in the laying of haploid eggs which lowers the sex ratio. The results obtained clearly points in this direction.

The present study suggests that for mass rearing of the parasitoid, *T. indicus*, when the ideal host plant *C. cajan* (TRIPATHI & KUMAR, 1984) is not available, the next choice should be *D. lablab* which is available throughout the year. For the purpose of obtaining a good female biased sex ratio a small number of parasitoid should be released at any given site.

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THE FIRST RECORD OF THE FAMILY ISCHNURIDAE (SCORPIONIDA : ARACHNIDA) FROM MAHARASHTRA WITH THE DESCRIPTION OF A NEW SPECIES OF A GENUS *IOMACHUS* POCOCK

D. B. BASTAWADE

Zoological Survey of India, Western Regional Station, 933 / A, Shivajinagar, Pune, India 411016

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The family Ischnuridae is being recorded for the first time from Maharashtra (Nasik District) with the description of a new species *Iomachus surgani* (Ischnuridae: Scorpionida).

(Key words: new species of *Iomachus*, Scropionida)

The genus *Iomachus* Pocock, 1893, occurs in S. India, accross Nellore in Andhra Pradesh to Yercaud in Shevaroy hills in Kerala through Nilgiri hills on east and Mangalore, Karnataka on West. So far only two nominal species and two nominal subspecies have been known to occur in this range. This genus has been reported for the first time from Maharashtra expanding the range of its distribution upto Surgana (20°N, 73.5°E) Dist. Nasik. The known species and subspecies have been redescribed and illustrated in details by Tikader & Bastawade (1983). The present communication deals with the description of a new species.

Iomachus surgani sp. nov. (Figs. 1–17)

General: Body of medium to small size, blackish brown to reddish brown, male more reddish; body surface entirely smooth and finely punctate; chelicerae smooth; pedipalps dorsoventrally flat and stout; legs weak; pectines weakly developed, delicate; genital operculi narrowed posteriorly in female; mesosoma entirely smooth and punctate; metasoma short, weak and smooth except segment V, telson globous on vesicle, aculeus short.

Dimensions: **Holotype** ♀ total length 41.25 mm; prosome 6.00 mm long, mesosoma 21.00 mm long, metasoma 14.25 mm long; pedipalp total length 19.75 mm; femur 4.75 mm long; patella 5.00 mm long, manus 6.00 mm long. Immovable finger 4.00 mm long.

Allotype ♂ total length 34.75 mm; prosoma 5.00 mm long, mesosoma 15.50 mm long, metasoma 14.25 mm long; pedipalp total length 16.50 mm; femur 4.00 mm long, patella 4.25 mm long, manus 5.00 mm long. Immovable finger 3.25 mm long.

Prosoma: Entire surface smooth, finely punctate without carinae, posterior furrows distinct, ocular tabercles smooth, poorly distinct; median eyes in the ratio 1 : 1.75 as in Fig. 1, lateral ocular tubercles indistinct with three eyes as in Fig. 2; anterior margin with deep median incisor, all margins smooth.

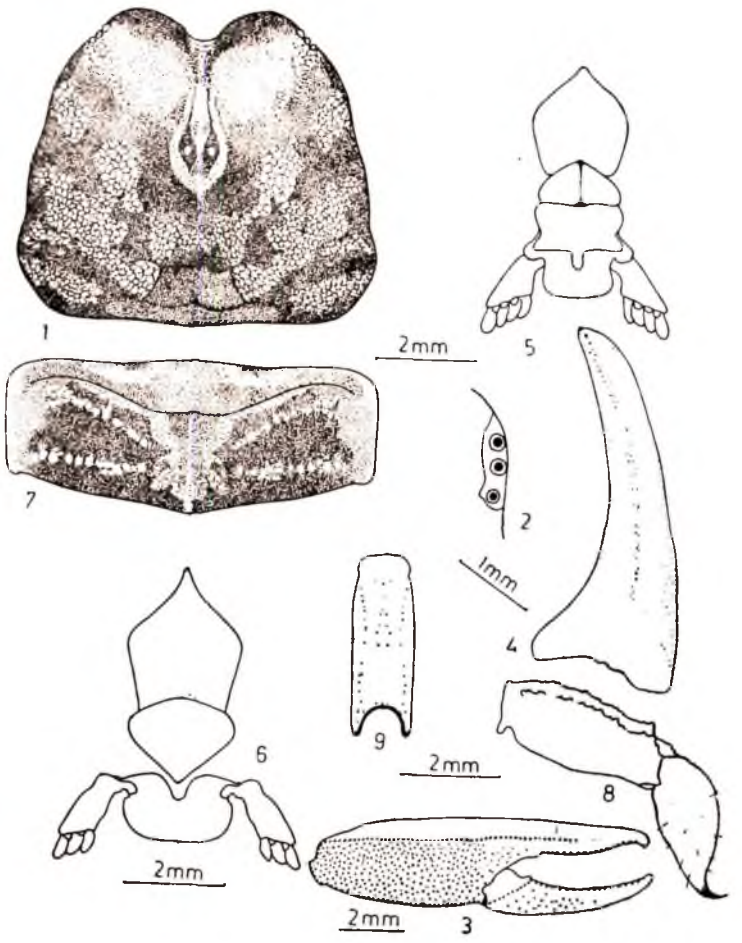

Fig. 1. Carapace, dorsal view; 2. Lateral eyes, lateral view; 3. Manus and fingers, exterior view; 4. Movable finger of manus, dorsal view; 5. Cephalothoracic sternum, genital operculum and pectines in ♂, ventral view; 6. Cephalothoracic sternum, genital operculum and pectines in ♀, ventral view; 7. Mesosomal tergite, dorsal view; 8. Metasomal segment V and telson, lateral view; 9. Metasomal segment V, ventral view.

Appendages: Chelicera smooth, fingers with typical family type dentition; pedipalp flat, stout, femur shorter than patella, weakly carinated, carinae strong and evenly crenulated, intercarinal space almost smooth, patella shorter than manus, smooth except anterior or inner weakly granular portion, manus carinated with exterior dorsal and ventral carinae evenly crenulated, intercarinal space weakly granular as in Fig. 3. Immovable finger shorter than femur, movable finger longer than femur, dentition on fingers minute and arranged in two rows as in Fig. 4. Trichobothriotaxi as in Figs. 10–17 but differs from so far known species and subspecies, especially, in the positions of *est*, *em* 1 and 2, *esb* 1–2 on

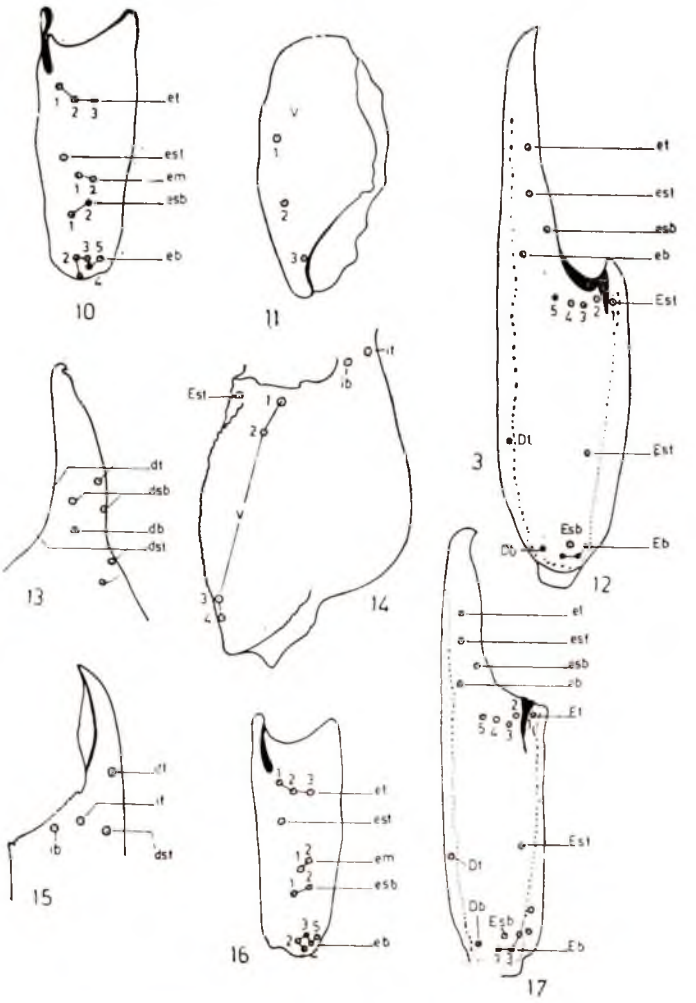

Fig. 10. Patella of pedipalp, exterior view for ♀; 11. Patella of pedidalp, ventral view for ♀; 12. Manus and immovable finger, exterior view for ♀; 13. Immovable finger, dorso-exterior view for ♀; 14. Manus, ventral view for ♀; 15. Anterior portion of manus and immovable finger, interior view for ♀; 16. Patella of pedipalp, exterior view for ♂; 17. Manus and immovable finger, exterior view for ♂.

patella (Figs. 10, 16) and *Est*, *Dt*, *Eb* 1, 2, 3, *Esb* and *Et* 1–5 on manus (Figs. 12–15, 17). Legs laterally flat, smooth, each tarsomere II provided with a ventral median row of minute, delicate spicules; pectines poorly developed, 1.25 times longer than wide in female and 1.50 in male, middle lamellae united, fulcra poorly distinguished, teeth 3/3 in female and 4/4 in male as in Figs. 5, 6.

Mesosoma: All tergites smooth, finely punctate, median portion raised, as a median carina on each II–VI segments as in Fig. 7; sternites III–VII also entirely smooth and finely punctate.

Metasoma: Cauda slightly more than two and a half times as long as carapace, basal segment slightly longer than wide, segments I–IV almost entirely smooth. Segment V as long as half the prosoma, smooth but ventrolateral and single ventral median carinae weakly and crenulated, anal rim delicately crenulated as in Figs. 8, 9; telson as long as segment V, smooth on vesicle and as long as segment IV, much globular, tapering distally; aculeus short, curved, delicately pointed as in Fig. 8.

Material examined : *Holotype* 1 ♀ : *Paratypes* 3 ♀ ♀ ; *Allotypes* 4 ♂♂ and 1 immature male and 3 young ones in spirit from Hiravpada near Hathgad, 42 km West of Vani on Nasik-Saputara Road, Tal : Surgana, Dist : Nasik, Maharashtra, India, 21.ii.1985, Coll. D. B. Bastawade & Party, will be deposited in Nationa Museum, Calcutta, shortly.

Habitat : The specimens have been collected from short burrows, just near the foot hill farm land sites, covered with bushy vegetation. The burrows are very peculiar and totally different from those of scorpionids. We examined about 10 burrows for collection which measured on an average 13—15 cm long, 3—3½ cm wide and 0.5 to 0.75 cm broad. These burrows were the simple tunnels, almost in vertical direction and ended abruptly. There were no formations of a pit or living chamber at the end, which is unlike the observations made by Raj Tilak (1970).

Discussion : This species is close to *I. punctulatus* Pocock but differs as follows : 1. in having entirely smooth patella of pedipalp. 2. Median eyes situated anteriorly in the ratio 1 : 1.75 whereas in other species it is 1 : 1.5 and dorsal surface of metasomal segments smooth whereas granular in *I. punctulatus* Poc. 3. Metasoma two and a half times as long as carapace whereas it is more in *I. punctulatus* Poc. and *I. laeviceps malabarensis* Poc. 4. Vesicle as long as segments IV whereas more than segment IV in *I. punctalatus* Poc. and shorter than segment IV in *I. nitidus* Poc. 5. Trichobothriotaxi differ in relative positions of *est' em* 1—2 on patella and *Est*, *Dt*. *Esb*, *Eb* and *Et* on manus from all other known species and subspecies.

This species is named after the taluk place of the locality.

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EFFECT OF REFRIGERATION OF EGGS OF *PURE MYSORE* RACE OF SILKWORM *BOMBYX MORI* L. AT BLUE STAGE

T. K. NARAYANA SWAMY & R. GOVINDAN

Department of Sericulture, College of Agriculture, Dharwad, India 580 005

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Refrigeration of multivoltine silkworm *(Bombyx mori* L.) eggs at blue stage for one, three, five and seven days resulted in reduction in hatching, maximum larval weight and effective rate of rearing. Larval mortality by the end of third instar was more. Similarly, weights of cocoon, cocoon shell and pupa, moth emergence and fecundity were also less compared to unrefrigerated check.

(Key words: Bombyx mori, egg, refrigeration)

INTRODUCTION

Hatching of eggs of silkworm can be delayed commonly by employing refrigeration. Eggs of multivoltine breeds of silkworm *(Bombyx mori* L.*)* cannot be refrigerated for long duration. It is particularly so in the case of aged eggs. DEVAIAH & THONTADARYA (1975) observed 79.21 per cent hatching when nine day old eggs of *Pure Mysore* xHS_6 were refrigerated for four days. As such an experiment was conducted to know the effect of refrigeration of eggs of multivoltine breed (*Pure Mysore*) at blue stage and the results are presented in this paper.

MATERIALS AND METHODS

The blue stage eggs of multivoltine silkworm breed, *Pure Mysore* were refrigerated at a temperature of 5°C for 1, 3, 5 and 7 days. The unrefrigerated control worms were also maintained. Four replications of three DEL's each were used for each treatment. The eggs were kept at room temperature of 25—26°C and relative humidity of 75—80 per cent before and after refrigeration. Extent of egg hatching was recorded. The worms under each treatment were reared in four replications of 100 worms each as per KRISHNASWAMI (1978) and observations on mortality at the end of third instar, maximum larval weight (weight recorded on seventh day of fifth instar), effective rate of rearing, weight of 10 each of cocoons, cocoon shells and pupae, moth emergence aud fecundity were recorded. Mortality at the end of third instar was considered to know the effect of egg refrigeration on early instar survival.

RESULTS AND DISCUSSION

The results of the effect of refrigeration on blue stage eggs for different durations are discussed below under respective headings, which are significantly different than that of control.

I. Pre-cocoon observations

The hatching percentage reduced from 83.70 to 21.60 at different durations of refrigeration, while in untreated control it was 94.38 (Table 1) and the treatment was significant. The mortality at the end of third instar ranged between 15.25 to 30.50 per cent in refrigerated batches and in control it was 2.00 per cent. Maximum larval weight for 10 worms was

TABLE 1. Effect of refrigeration of silkworm eggs at blue stage on pre-cocoon.

Observations	Duration of refrigeration (Days)				unrefrige-rated cotrol
	1	3	5	7	
Egg hatching %	83.70 (66 95)*	75.36 (60.93)	53.20 (47.41)	21.60 (28.28)	94.38 (77.83)
Mortality at the end of 3rd instar %	15.25 (23.74)	21.00 (27.70)	30.50 (34.13)	30.50 (34.13)	2.00 (8.00)
Maximum larval weight of 10 worms (g)	17.46	15.44	15.02	14 85	21.73
Effective rate of rearing (%)	64 25 (53.95)	50.25 (45.72)	39.55 (39.60)	38.00 (38.65)	94.25 (77.50)

	SEM ±	C D at 5%
Egg hatching	1.03	3.18
Mortality at the end 3rd instar	0.83	2.56
Maximum larval weight	0.1011	3.3114
Effective rate of rearing	1.16	3.56

*Figures in parentheses are transformed values.

TABLE 2. Effect of refrigeration of silkworm eggs at blue stage on postcocoon.

Observations	Duration of refrigeration (days)				unrefrige-rated control
	1	3	5	7	
Weight of 10 cocoons (g)	9.46	9.23	9.13	8.36	11.07
Weight of 10 cocoon shells (g)	1.17	1.10	1.09	1.06	1.36
Weight of 10 pupae (g)	8.29	8.13	8.04	7.30	9.67
Moth emergence (%)	82.52 (66.05)*	79.35 (63.70)	75.23 (60.83)	72.01 (58.72)	94.70 (78.13)
Fecundity (number of eggs per female)	441.20	482.20	458.40	431.20	425.40

	'F' test	SEM±	C D at 5%
Cocoon weight	*	0.1404	0.4326
Cocoon shell weight	*	0.0260	0.0801
Pupal weight	*	0.1271	0.3916
Fecundity	NS	24.65	73.90
Egg hatching	*	2.48	7.43

*Figures in parentheses are transformed values.

21.73 g in control and in respect of refrigeration, it varied from 14.85 to 17.46 g, the maximum being with one day refrigeration. The cocooning was 38.00 to 64.25 per cent under refrigeration while it was 94.25 per cent in check. Five and seven days refrigeration had similar effect (Table 1). The weight of 10 cocoons was high (11.07 g) in the unrefrigerated control and it was low (83.6 g) with seven days of refrigeration, whereas the same under one, three and five days was statistically same (9.13 to 9.46 g) (Table 2). Cocoon shell weighed more (1.36 g/10 shells) in control. It ranged from 1.06 to 1.17 g for refrigerated. In the case of untreated check significantly more weight of 9.67 g/10 pupae was recorded. Refrigeration effect for one and three days was statistically similar (Table 2).

2. Moth emergence and fecundity

The emergence of moths varied from 58.72 to 66.05 per cent with different durations of refrigeration (Table 2) and in respect of control it was higher (78.13 per cent). Though the fecundity ranged from 425.40 to 482.20 eggs/female in respect of various durations of refrigeration and control, it was found non-significant. According to KRISHNASWAMI *et al.* (1973), hatching of eggs can be delayed at blue egg stage by cold storing for about a week at 5°C. But in the current study hatching was severely affected as a result of refrigeration of eggs at blue stage even for five days which is in conformity with the observations reported by DEVAIAH & THONTADARYA (1975). There was significant difference in per cent hatching when nine day old eggs of *Pure Mysore* xHS_6 were refrigerated for different durations and the lowast of 79.21 per cent hatching was encountered in case of eggs refrigerated for four days.

In view of the present results, it may be concluded that refrigeration of eggs of *Pure Mysore* race at blue stage affects the economic characters drastically.

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SEASONALITY AND REPRODUCTION IN *GREENIDEOIDA CEYLONIAE* GOOT (HOMOPTERA : APHIDIDAE)

BASANT K. AGARWALA & S. ROY

Department of Life Science, Calcutta University Post Graduate Centre, Agartala, India 799 004

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Greenideoida ceyloniae Goot, a monoecious aphid species of *Mesua ferrea* (Guttiferae), is oriental in origin and distribution. Effects of seasonal changes in the host conditions on the biological attributes of the aphid is investigated in this study.

(Key words: seasonality, reproduction, aphids)

INTRODUCTION

Greenideoida ceyloniae v. d. Goot belongs to subfamily Greenideinae whose members have evolved in the Lauraceous forests of South-East Asia. These aphids do not exhibit host alternation but lead autoecious life cycle on woody plants. Out of 180 species under 11 genera recorded from the Oriental Region (AGARWALA & GHOSH, 1985), 82 species under 10 genera are represented in India (AGARWALA & GHOSH, 1984) and none of these species was previously studied for its developmental biology and seasonal variation.

An investigation on seasonality and reproduction in *G. ceyloniae* in Agartala, North-East India, was taken up during 1983—1984 to record the seasonal variation in the developmental period, prereproductive, reproductive and postreproductive periods, reproductive activity, and adult longevity in the apterous viviparous females.

DIXON & WELLINGS (1982) have reviewed such studies in the aphids of temperate regions. This evidently is the first account on any aphid from Indian region.

MATERIALS AND METHODS

1. Ten to 15 adult apterae collected each month in the first week were dissected under stereoscopic microscope for recording the number of developing embryos. The largest of these embryos were mounted on the slide for the measurement of their body length.

2. Two sets of experiments, each comprising four saplings of *M. ferrea* in potted conditions, were kept in semi-natural condition once during winter (Nov—Jan) and again during spring (Feb—Mar). In each set fourth instar nymph of apterous viviparous females were placed on the leaves using leaf cages. Observations at 24-hours interval were made to record the developmental period of successive instars followed by prereproductive, reproductive and postreproductive periods. Fecundity, per day and total, were recorded simultaneously. In winter, saplings with young and growing leaves were chosen for the study but in spring, saplings were confined to warm conditions of the room and relatively mature leaves were used for study. This was done to synchronise the conditions existing in *M. ferrea* in nature.

Average temperature and relative humidity obtained for the period of study were 19.9°C and 81% in winter and 22.7°C and 59% in spring respectively.

RESULTS AND DISCUSSION

1. Development period

The total duration of development from the newly hatched nymph to last moult did not vary significantly in the two seasons. However, in winter mean duration of first instar was slightly longer than their counterparts in spring when the durations of the second and third instars were slightly higher. No variation was noticed in the duration of fourth instar. Although such minor variations in the two seasons do not seem to be attributable to any major bio-ecological factors of host/aphid relationship, perhaps young and growing leaves in winter provided favourable conditions for a sligthly quicker development of early instars and this effect was neutralised in the late instars.

2. Pre-reproductive, reproductive and post-reproductive periods

Before the onset of reproduction, aphids undergo an interval period of variable durations (DIXON, 1970, 1972). In *G. ceyloniae* this period is about 1 day during winter and 2.37 days in spring. In winter, aphid commences reproduction on the vigorously growing leaves within 24 h of final moult whereas mature leaves in spring delays it for more than 2 days.

Once reproduction commenced it continued for several days, 12.7 days in winter and 8.5 days in spring. This brings out that host condition is equally effective in exercising its due role in the reproductive activity of the aphid which dwindles significantly in spring in comparison to winter. However, post reproductive period remained relatively unaffected and it was 1.7 days in winter and 2.5 days in spring.

3. Reproductive activity

Although no significant differences in total number of nymphs laid by aphids in winter (25.5) and spring (22.9) were noticed, the per day reproductive activity in spring was higher by 35.18% which was, perhaps, responsible for compensating the reduction in reproductive period and nearly square up the tally of total reproductive activity of the two seasons. This leads to the assumption that reproductive potential in this greenideine aphid is pre-planned and host condition can affect it to a slight extent only. Generally the nutritional status of the host determines the fecundity of aphid and the latter moniter its reproductive activity anticipating the host condition well in advance (DIXON & WELLING 1982). How this phenomenon is related to this greenideine aphid is yet to be ascertained.

4. Adult longevity

Adult apterae occurred throughout the period of aphid incidence on *M. ferrea*. Adult longevity in the two seasons was assessed by confining the aphids after final moults on its host under leaf caging. Host conditions were synchronised with that existing in nature.

In winter adult aphid lives 40% longer on younger leaves. In spring, on mature leaves aphid life (12.5 days) was shorter by 5 days. Longer life in the winter (17.5 days) was mainly due to longer reproductive period which in spring sharply declined.

5. Number of well-developed embryos

At weekly interval 10—15 adult apterae aphids were dissected during winter and spring to record the number of well-developed embryos with pigmented eyes and the size of largest

embryo in each aphid. This was done to correlate the number of nymphs laid per day with the number of embryos developing in the gonad.

In winter fecundity per day was 35.18% less than in spring and correspondingly aphids in winter carried 36.4% less embryos with pigmented eyes than in spring. This presents a close link in the number of embryos developing in the gonad and number of nymphs to be laid in a single day. There was no discernable variation in the size of the largest embryo in the aphids of two seasons, these being 0.68 mm in winter and 0.70 mm in spring, which suggests that intragonadal development is not influenced by seasonal changes in host at least in the body length of embryo.

Instances of drastic changes in the biological attributes of aphids in response to seasonal changes in the habitat quality are quite numerous (DIXON & WELLINGS, 1982; KENNEDY & STROYAN, 1959; DIXON, 1970) but *G. ceyloniae* do not seem to be much influenced by the changes in habitat quality except in daily fecundity and developmental duration of early instars as revealed in this study which, possibly, were due to the influence of ephemeral nutrition supply in the young and mature leaves. Little to very little changes in the other biological attributes suggest that greenideine aphids have established a stable relationship with the changing qualities of the host without unduly being influenced. This is perhaps the reason that these aphids are rather host specific and restricted in distribution.

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BRIEF COMMUNICATION

NEW RECORDS ON THE INCIDENCE OF SPOTTED BEETLE, *OIDIS AFFINIS* JACOBY (COLEOPTERA : CHRYSOMELIDAE) ON ELEPHANT FOOT YAM AND THE SCALE INSECT, *ASPIDIELLA HARTII* COCKERELL (HOMOPTERA : DIAPSIDIDAE) ON TARO

K. S. PILLAI & P. RAJAMMA

Central Tuber Crops Research Institute, Trivandrum, India 695 017

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The spotted beetle, *Oidis affinis* damaging the foliage and pseudostem of *Amorphophallus* and the scale insect *Aspidiella hartii* infesting the corms of taro have been reported for the first time in India.

(Key words: Oidis affinis, elephant foot yam, taro, *Aspidiella hartii)*

Elephant foot yam *(Amorphophallus companulatus* L.*)* was considered as a crop less attacked by arthropod pests. However, a few insects have been reported as pest on *Amorphophallus* in our country (NAIR, 1975; LAL & PILLAI, 1977; PALANISWAMI & PILLAI, 1979). Recently severe infestation by the spotted beetles *(Oidis affinis)* was observed in the farm of Central Tuber Crops Research Institute, Trivandrum. The adults and the grubs feed on the leaf and pseudostem and make deep scars on the pseudostem; severely infested plant withers away. The grubs bore into the pseudostem and cause stem splitting and decay. The tunnelling by the grubs and deposition of slimy secretion mixed with excreta result in greater decay of pseudostem. Besides this direct damage, the injury caused by the grubs helps to increase the incidence of sclerotium rot on the pseudostem. The infestation ranged from 15 to 25% during July-August.

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The incidence of *Oidis affinis* on *Amorphophallus* is the first report in our country or in any other part of the tropical world. The spotted beetle has been reported feeding on paddy (FLETCHER, 1914; NAIR, 1975). The authors have recently found the beetle feeding on the weed *Bocharia* sp. Other species like *O. bipunctatus*, *O. collaris* and *O. scutallata* are reported infesting maize, rubber, grapevine and potato (MISRA et al., 1979).

Taro *Colocasia esculenta* (L) Schoot is attacked by a large number of pests in the tropical regions (PLANISWAMI & PILLAI, 1978; BUTANI & VERMA, 1981; MICHELL & MADDISON, 1983). MICHELL & MADDISON (1983) have given a comprehensive list of pests infesting taro all over the world and mentioned about 40 insect and non-insect pests attacking roots and tubers. Among them the most serious ones are taro beetles *(Papuana* spp.), scarabid beetles and nematodes. Scales and mealy bugs have also been reportep as infesting roots and tubers of taro.

Recently taro corms under storage at Central Tuber Crops Research Institute have been found severely infested by a scale insect. The pest was first noted on the tubers procured from the Trichur Centre of NBPGR. The scales multiply in large numbers and cover the entire surface of the tubers presenting a white mealy appearance. The attacked corms shrink and shrival and the viability is lost. The scale has been identified as *Aspidiella hartii* by the taxonomist of Commonwealth Institute of Entomology, London. *A. hartii* has not so far been reported on taro in India. MICHELL & MADDISON (1983) have reported *A. hartii* infesting corms of 'eddoe' *(C. esculenta* var. *antiquorum)*.

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REPORTS AND NEW RECORDS

MACONELLICOCCUS HIRSUTUS (GREEN), A NEW MEALY BUG PEST OF GROUNDNUT IN ANDHRA PRADESH

D. V. Siva Rao & S. Srinivasan

Regional Agricultural Research Station, S. V. Agricultural College, Tirupati, India 517 502

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Maconellicoccus hirsutus (Green) which was earlier known as a pest of jute and mesta, is newly recorded in Andhra Pradesh as a pest of groundnut feeding on the pegs, pods and roots of the plant.

(Key words: mealy bug, coccid, Pseudococcidae, Hemiptera, mesta)

The mealy bug, *Maconellicoccus hirsutus* (Green) (Pseudococcidae) was found for the first time feeding on the roots, pods and pegs of the groundnut plants, grown at the Agricultural Research Station, Perumallapalle, Chittoor district, Andhra Pradesh during the 1981—1982 postrainy season and during the following year. The affected plants appeared in patches.

M. hirsutus was earlier recorded as a serious pest of jute *(Corchorus* sp.*)* and mesta *(Hibiscus* sp.*)* infesting the aerial parts of the plant (Dutt, 1959). However, in the case of groundnut, the mealy bug was found feeding only on the underground parts of the plant such as pegs, pods and roots. This resulted in stunted growth of the plants and illdeveloped pegs and pods. While the mealy bug infested jute and mesta from March to December (Singh & Ghosh, 1970) it was found to infest groundnut during February—April.

The authors are grateful to Dr. D. J. Williams, Commonwealth Institute of Entomology for identifying the mealy bugs and to Dr. C. Sreeramulu, Associate Director of Research, Regional Agricultural Research Station, Tirupati for the facilities provided.

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NEW APHIDIID HOST RECORD OF APHID HYPERPARASITOID (HYMENOPTERA) FROM INDIA

Rajendra Singh, Mamta Srivastava & P. N. Srivastava*

Aphid biocontrol Laboratory, Department of Zoology, University of Gorakhpur, Gorakhpur, India 273 009

*Department of Zoology, Budha P. G. College, Kushinagar, Deoria, U. P.

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Aphid hyperparasitoid, *Dendrocerus carpenteri* (Curtis) has been recorded for the first time from India attacking primary aphidiid parasitoid, *Trioxys indicus* Subba Rao & Sharma.

(Key words: New host report, *Trioxys indicus,* hyperparasitoid, *Dendrocerus carpenteri)*

During the course of study of field ecology of *Trioxys indicus* Subba Rao & Sharma (Hym. : Aphidiidae) a parasitoid of pigeonpea aphid, *Aphis craccivora* Koch (Hom. : Aphididae), the authors have noticed 5 hyperparasitoids from Uttar Pradesh belonging to different families of Hymenoptera till 1982. These are *Alloxysta pleuralis* Cameron (Singh

& Sinha, 1979), *Phaenoglyphis* sp. (Singh *et al.*, 1981; Alloxystidae); *Aphanogmus* sp., *Ceraphron* sp. (Ceraphronidae) and *Litomastix* sp. (Encyrtidae) (Singh *et al.*, 1982). In addition to these, 4 more hyperparasitoids of *T. indicus* are known, *viz.*, *Lygocerus* sp. (Ceraphronidae), *Alloxysta* sp. (= *Charips* sp.) (Subba Rao & Sharma, 1962), *Asaphes suspensus* Nees (Pteromalidae) and *Prionomitus* sp. (Encyrtidae) (Bhagat, 1983).

Recent collections of the aphids from this region have yielded one more hyperparasitoid, *Dendrocerus carpenteri* (Curtis) (Ceraphronidae) from *T. indicus*, a widespread species (Dessart, 1970). *D. carpenteri* was earlier reported from Kashmir (Bhagat, 1983) as a hyperparasitoid of two primary aphidiid genera : *Aphidius avenae* Haliday bred from host aphid, *Microsiphum rosae* Linn., *Aphidius* sp. reared from aphid, *Uroleucon sonchi* Linn., *Praon abjectum* (Haliday) reared from aphid, *Aphis grossulariae* (Walker and *P. dorsale* (Haliday) attacking aphid, *Amphicercidus tuberculatus* David, Narayanan & Rajasingh. Therefore, *T. indicus* is a new host for *D. carpenteri*.

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RECORD OF A PARASITE, *EUDEROMPHALE* SP. (EULOPHIDAE : HYMENOPTERA) ON *LIPALEYRODES EUPHORBIAE* DAVID AND SUBRAMANIAM (ALEYRODIDAE : HOMOPTERA) FROM INDIA

A. Lima Rose Jeritta & B. V. David

Fredrick Institute of Plant Protection and Toxicology, Padappai, India 601 301

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The occurrence of a parasite *Euderomphale* sp, nr. *bemisiae* Viggiani on the aleyrodid *Lipaleyrodes euphorbiae* David and Subramaniam has been reported for the first time. This is the first record of the genus *Euderomphale* from India.

(Key words: Euderomphale sp., *Lipaleyrodes euphorbiae)*

The natural enemies of aleyrodids exceed more than 200 species (Mound & Halsey, 1978). However, no information is available on the natural enemies of the genus *Lipaleyrodes*.

While studying the biology of *Lipaleyrodes euphorbiae* David & Subramaniam on its host *Phyllanthus fraternus* Webster (= *P. niruri*) during February to June 1985 a number of immature stages, particularly the pupae, were found parasitised. The parasites were reared out and their identity established. It was found from the available literature that no parasite or predator has been reported so far to attack any stage of *L. euphorbiae* and this forms the first record from India.

Earlier reports indicate the occurrence of species of the genus *Euderomphale* on eleven other species of aleyrodids viz., *Euderomphale* sp. on *Aleurodicus flavus* and *Aleyrodes lonicerae* and *Asterobemisia carpini*, *E. aleurothrixi* Dozier on *Aleurothrixus floccosus*, *E. cerris* (Enderlein) on *Aleyrodes proletella*, *E. flavimedia* (Howard) on *Aleyrodes* sp., and *Aleyrodes aureocincta*, *E. quericicola* Dozier on *Tetraleurodes* sp., *E. vittata* Dozier on *Aleurodicus* sp., and *Aleurodicus antillensis* (Mound & Halsey, 1978). The present report of *Eudermophale* sp. nr. *bemisiae* Viggiani as a paraiste of *L. euphorbiae* forms a new record from India.

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NEW REPORT OF PARASITES OF GROUNDNUT LEAF WEBBER, *APROAEREMA MODICELLA* DEVENTER (LEPIDOPTERA : GELECHIIDAE)

S. SRINIVASAN & D. V. SIVA RAO

Regional Agricultural Research Station, S. V. Agricultural College, Tirupati, India 517 502

(Received 31 July 1985)

Two new parasites, namely, *Chelonus blackburni* and *Habrocytus* sp. were recorded for the first time on the larvae of *Aproaerema modicella* Dev., a serious pest of groundnut in Andhra Pradesh.

(Key words: Groundnut leaf webber, new larval parasites)

The groundnut leaf webber, *Aproaerema modicella* Deventer is known as a serious pest of groundnut causing considerable losses in yield throughout South India (Kulshreshta, 1964). As chemical control of the pest, particularly on rainfed groundnut was not economically feasible, a study to find out the natural mortality factors of the pest was taken up at the S. V. Agricultural College Farm, Tirupati (Andhra Pradesh) from 1983-1984 *Kharif* and *Rabi* seasons, the results of which, concerning parasites, are presented in this paper.

A large number of larvae were collected from the fields at monthly intervals and kept in the laboratory for emergence of parasites. The extent of parasitisation during different months of observation is given in Table 1.

During the months from September to November and again from January to March, the extent of parasitisation by various parasites was more than in

TABLE 1. Extent of parasitisation of *A. modicella* by different parasites.

Month	per cent larvae parasited
July, 1983	Nil
August	3.2
September	19.2
October	25.4
November	17.0
December	1.4
January 1984	4.2
February	12.0
March	24.2
April, May & June	Nil

other months. These were the months in which maximum pest populations were also found in the *Kharif* and *Rabi* groundnut crops respectively (Anon. 1982, 1983). The larval parasite complex at Tirupati essentially comprised of hymenopterans and they were, the braconids *Chelonus blackburni* Cameron, *Apanteles* sp. and *Microbracon* sp., the eulophids *Tetrastichus* sp. and an unidentified eulophid, the eurytomid *Eurytoma* sp. the pteromalid *Habrocytus* sp. and an unidentified eupelmid and bethylid.

Among the other natural enemies, robber flies (Diptera: Asilidae) were found to predate on the larvae besides a few spiders. Mermithids (nematodes) were noticed to emerge from the larvae during September – October which coincided with North – East monsoon rains. The larvae were also found infected by an entomogenous fungus, *Aspergillus flavus* during the rainy season.

Subbarao *et al.* (1965), Kothai (1974) and Bhatnagar & Davis (1979) have reported earlies all the parasites now recorded on the pest at Tirupati except *Chelonus blackburni* Cameron and *Habrocytus* sp. However, *Chelonus* sp. has been listed by earlier workers as a larval parasite of *A. modicella* but not confirmed as *C. blackburni*. Thus *Chelonus blackburni* and *Habrocytus* sp. are new records as larval parasites of *A. modicella* on groundnut.

C. Blackburni has given promising results in the control of cotton boll worms in U. S. A. and India (Bryan *et al.*, 1973; Legner & Medved 1981; Swamiappan & Balasubramanian (1980). Attempts are therefore under way to find out the suitability of this parasite as a component in the integrated control of *A. modicella.*

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OBSERVATIONS ON SPIDERS (ORDER : ARANEAE) PREDACIOUS ON THE COCONUT LEAF EATING CATERPILLAR *OPISINA ARENOSELLA* WLK. (= *NEPHANTIS SERINOPA* MEYRICK) IN KERALA : BIOLOGY OF *RHENE INDICUS* TIKADER (SALTICIDAE) AND *CHEIRACANTHIUM* SP. (CLUBIONIDAE)*

B. SATHIAMMA, S. P. JAYAPAL & G. B. PILLAI

Biological Control Laboratory, Central Plantation Crops Research Institute, Regional Station, Kayangulam, Krishnapuram, Kerala, India 690 533

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Biology of *Rhene indicus* and *Cheiracanthium* sp. was studied under laboratory conditions. The different life stages were reared using caterpillars of *Opisina arenosella* as prey. *R. indicus* males required a mean of 83 (range 67—104) days after hatching to maturity, reached adulthood after six moults and lived for an average of 51.25 (range 25—77) days. Females required a mean of 79.5 (range 59—105) days after hatching to maturity, reached adulthood after six moults and lived for an average of 139.83 (range 71—296) days. Females were found to oviposit 6—31 days after mating, produced 7—10 broods and the number of spiderlings emerged from single egg mass varied from 9—37. The spider started feeding on early instar caterpillars of *Opisina* from the second instar onwards and the prey consumption ranged from 2—207 caterpillars.

Males of *Cheiracanthium* sp. required a mean of 214.6 (range 162—261) days after hatching to maturity, reached adulthood after 12 moults, and lived for an average of 74.5 (range 35—122) days as adult. Females required a mean of 207 (range 169—248) days after hatching to maturity, reached adulthood after 12 moults and lived for an average of 85.7 (range 51—127) days as adult. Females oviposited in 8—30 days after mating, produced one to four broods and the number of spiderlings emerged from single egg mass varied from 9—86 with an average of 49.1. Except the first instar all the eleven instar spiderlings consumed *Opisina* caterpillars and the rate of feeding was observed to vary from 2—151.

(Key words: predacious spiders, *Opisina arenosella)*

Rhene indicus Tikader and ***Cheiracanthium*** sp. are two of the most widely distributed spiders predacious on ***Opisina arenosella*** in Quilon and Alleppey districts of Kerala, where this pest is a serious problem (SATHIAMMA *et. al.* unpublished). The predacious habits of the spiders were studied by the authors in detail (SATHIAMMA *et. al.* unpublished). The increasing interest on the high feeding potential of the spiders and the significant role they play in the natural suppression of this key pest of the coconut palm, have necessitated detailed studies on their biology.

Information available on the biology of the spiders is relatively limited. The

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developmental history of *Latrodectus mactans* (Fabr.) at different rates of feeding was studied by DEEVEY (1949). MANSOUR *et al.* (1980) studied the biology of *Cheiracanthium mildei* and PECK & WHITCOMB (1970) the biology of *C. inclusum*. The present paper embodies the results of the study on the biology of *Rhene indicus* and *Cheiracanthium* sp. under laboratory conditions.

MATERIALS AND METHODS

Spiders were reared individually in glass containers (size 17×6.5 cm) in the laboratory under a temperature range of 22—34°C and relative humidity range of 32—96%. They were fed with the early instar caterpillars of *O. arenosella*. Observations on the duration of different life stages, moulting, longevity and feeding potential were recorded daily.

RESULTS AND DISCUSSION

1. Rhene indicus Tikader

The female spins a resting cell and hides herself in this cell for egg laying. The eggs are covered by a strong egg sac. They are semitransluscent, yellowish-white and spherical. Egg period is completed in 12 days. The newly emerged spiderlings are whitish yellow. The first moult takes place at about the seventh day after emergence from the egg sac. The body of the spiderling is covered with hairs and spines and these become dark before 24th hr of the first moulting *R. indicus* completed its life cycle after the sixth moult (Fig. 1). The female spider completed development in 79.5 (range 59—105) days and male 83 (range 67—104) days (Table 1). The duration of the egg and first instar spiderling were uniform for both male and female spiders. All the subsequent instars recorded widely varying durations. Adult females lived, on an average, for 139.83 days and males 51.25 days. The males were short-lived. The females attained adult phase earlier and lived for longer periods than the males.

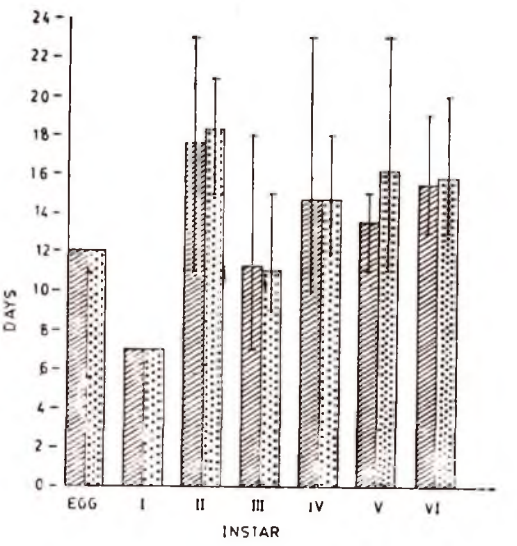

Fig. 1. Duration of immature stages of *Rhene indicus*

The female spider constructed a thin horizontal webbing inside the glass jar and conceals inside the webbing, which forms the egg sac. The eggs are laid in this sac. The egg sac is made more tightly webbed and kept completely sealed off from outside. The female remains in close contact with the egg sac for the entire period, periodically moves around it and palpates it. The first instar spiderlings, which remain inside the resting cell, were also taken care of by the mother spider till they undergo the first moult. During this period the mother consumes only very little food.

Mature fertilised females laid 7—10 egg masses in captivity. The female oviposited from 6 to 37 days after mating. The number of egg massess which a female produced was directly proportional to the life span of the female. The virgin female

TABLE 1. Days to maturity, number of immature stadia and adult life span of *Rhene indicus*.

Duration	female			male		
	days to maturity	No. of immature stadia	adult life span (days)	days to maturity	no. of immature stadia	adult life span (days)
Mean	79.5	6	139.83	83	6	51.25
Maximum	105.0	6	296.00	104	6	77.00
Minimum	59.0	6	71.00	67	6	25.00
No. of replications	10	10	6	6	6	4

TABLE 2. Consumption of caterpillars of *O. arenosella* by the immature adult stages of *Rhene indicus*.

Stage	prey consumption per stage				prey consumption per day			
	female		male		female		male	
	mean	range	mean	range	mean	range	mean	range
I	0	0	0	0	0	0	0	0
II	7.63	6—12	6.00	4—8	0.43	0.31—0.57	0.32	0.26—0.41
III	5.00	3—8	5.67	4—9	0.44	0.27—0.77	0.51	0.33—0.66
IV	6.27	3—13	5.83	4—9	0.40	0.16—0.86	0.38	0.27—0.52
V	5.00	2—9	6.83	4—12	0.35	0.15—0.54	0.40	0.30—0.52
IV	7.18	4—10	8.00	5—15	0.46	0.25—0.62	0.51	0.25—1.00
Adults	97.88	49—207	15.30	12—31	0.70	0.38—1.14	0.30	0.21—0.52

produced infertile egg massess. A single egg mass gave emergence to 9—31 spiderlings in laboratory cages.

R. indicus, at all stages of its growth, consumed *Opisina* caterpillars and the rate of feeding varied from 2 to 207 caterpillars (Table 2). Adult spiders fed more than the immature stages and the females showed high feeding potential than the males. The prey consumption per stage varied from 49 to 207 in the case of the female and 12 to 31 in the male. The rate of prey consumption per predator was observed to be 0.38 to 1.14 in the female and 0.21 to 0.52 in the male. The first instar spiderlings depended on the egg yolk for their food and were never observed to feed on the prey caterpillars. However, from the second instar to the sixth and the adult spiders consumed early instar *Opisina* caterpillars.

2. *Cheiracanthium* sp.

The female spider conceals herself in a brood cell constructed prior to the

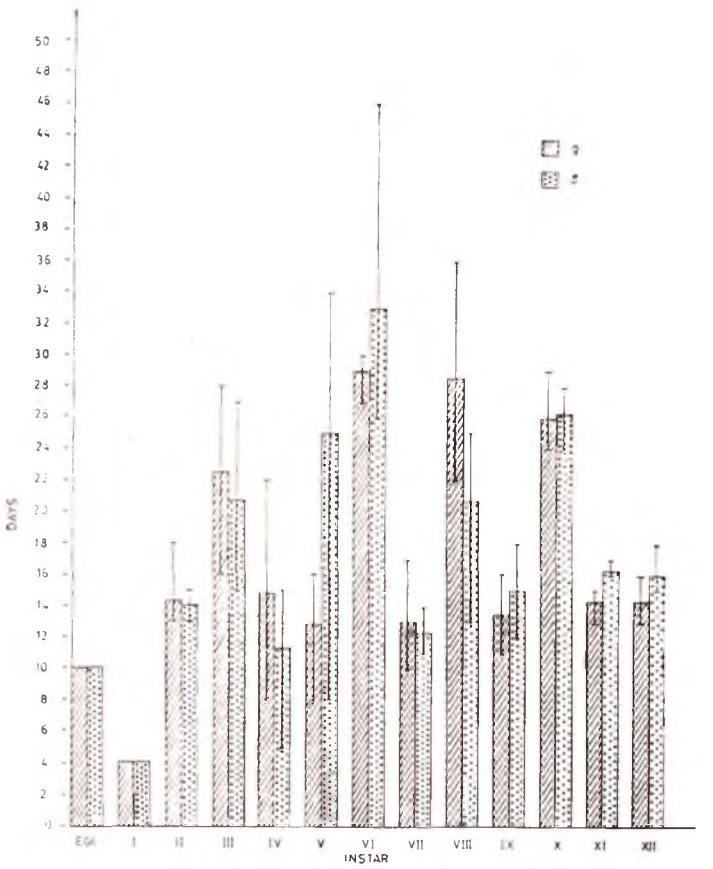

Fig. 2. Duration of immature stages of *Cheiracanthium* sp.

oviposition and lays the eggs. The eggs are semitranslucent, yellowish white, spherical and measure about 2 mm in diameter. About the sixth day after oviposition, the mother spider gradually loosens the egg sac. First instar spiderlings emerge from the eggs after the tenth day of oviposition. The newly emerged spiderlings are whitish yellow. By about the third day of emergence, hairs and spines appear on their appendages.

Under labotatory conditions *Cheiracanthium* sp. matures after the twelfth moult (Fig. 2). The female spider requires a mean of 207 days (range 189—248) and male 214.6 (range 162—261) for its development.

The first two stadia are more or less uniform in duration with an egg period of 10 days and first instar of 4 days. All the subsequent instars took widely varying durations. Females developed rather earlier than the males. Adult females on an average lived for 85.7 days (range 51—127) and the males 74.5 days (range 35—122).

TABLE 3. Consumption of caterpillars of *O. arenosella* by the immature and adult stages of *cheiracanchium* sp.

Stage	consumption per stage				consumption per day			
	female		male		female		male	
	mean	range	mean	range	mean	range	mean	range.
I	0	0	0	0	0	0	0	0
II	3.00	3—3	4.33	3—7	0.21	0.16—0.23	0.30	0.21—0 46
III	7.00	5—7	6.33	5—8	0.31	0.30—0.32	0.32	0.22—0.40
IV	4.50	3—6	4.00	2—7	0.32	0.22—0.37	0.41	0.33—0.50
V	4.75	3—8	14.00	4—22	0.38	0.21—0.61	0.54	0.47—0.66
VI	12.75	10—15	14.66	5—21	0.44	0.40—0.53	0.43	0.18—0.68
VII	5.50	3—8	9.33	5—14	0.41	0.30—0.50	0.77	0.41—1.27
VIII	13.50	7—26	15.00	14—17	0.47	0.31—0.72	0.78	0.54—1.07
IX	10.75	8—14	10.67	9—13	0.81	0.61—1.24	0.71	0.66—0.72
X	25.25	20—39	25.00	21—31	0.97	0.72—1.50	0.94	0.82—1.14
XI	27.50	19—35	26.00	22—28	1.93	1.26—2 33	1.60	1.29—1.75
XII	22.36	27—32	36.33	28—43	2.07	1.87—2.28	2.28	1 86—2.86
Adult	101.98	60—151	52.15	24—86	1.19	0.84 -3.00	0.70	0.31—0.73

One day prior to oviposition the female spider constructs a resting cell, one side of which is kept open. During oviposition an egg sac is constructed inside the resting cell. The egg sac is spherical and it is woven more titghtly and densely covered than the resting cell and is always sealed off completely from the external environment.

After egg laying the mother spider remains in close contact with the egg mass for the entire period, moving around it periodically and touching it with her palpi. The first instar spiderlings are also taken care of by the mother till the first moult. She takes only very little food during this period. When the spiderlings are ready for an independant life the mother tears of the fabric of the brood cell and this enables the spiderlings to come out.

In glass cages the fertilised females produced one to four egg masses. The number of egg massess produced was directly proportional to the life span of the female. The virgin females produced infertile egg masses, which in all cases degenerated in a few days. On an average 49.1 (range 9—86) spiderlings emerged from single egg mass, and this number varied from spider to spider and brood to brood of the same spider. The female oviposited 8—30 days after mating and spent about 14 days with the eggs and spiderlings. The females took, on an average, 23.85 days (range 17—31) between successive ovipositions.

The females lived for longer periods than the male, but duration of development varied from progeny to progeny.

Cheiracanthium sp. feeds on all stages of *O. arenosella*. Second and third instar spiderlings preferred the early instar caterpillars of *Opisina*. Maximum consumption was noted in the tenth, eleventh and twelfth instars and adult spiders (Table 3). Considering the per day consumption the feeding rate increased progressively from the second instar to the final instar. As compared to the immature stages, the rate of consumption was quite high in the adult spiders, the females consumed, on an average, 101.98 (range 60—151) and males consumed 52.15 (range 24—86) *Opisina* caterpillars as compared to the maximum feeding of 22.36 and 36.33 caterpillars in the twelfth instar female and male, respectively.

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EFFECT OF 25-AZACHOLESTEROL ON DEVELOPMENT IN *LOCUSTA MIGRATORIA* (ORTHOPTERA : ACRIDIDAE)

VERSHA GOEL & H. C. AGARWAL
Department of Zoology, University of Delhi, Delhi, India 110 007

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The azasteroid, 25-azacholesterol was found to have an inhibitory effect on the growth and development of *Locusta migratoria*. Both adult emergence and per cent survival decreased with an increase in azasteroid concentration. However, no larval-adult intermediates were observed.

(Key words: locust, *Locusta migratoria*, 25-azacholesterol)

Insects have a dietary requirement of sterols for development and reproduction, as they are unable to synthesize sterols, unlike most other animals and plants. This requirement can be met generally by cholesterol (SVOBODA *et al.*, 1978). Sterols serve as a precursor of insect moulting hormones (KARLSON & HOFFMEISTER, 1963). An interference of the sterol metabolism in insect may adversely effect its growth and may eventually kill them. Certain steroidal compounds such as azasteroids which are structurally similar to cholesterol have been shown to affect the larval growth and development of a few insects (SVOBODA & ROBBINS, 1971). The inhibitory effects of these compounds on egg production and their hatchability have also been reported in southwestern corn borer (AL-IZZI & HOPKINS, 1982). However, no such studies have been reported in the locust, *Locusta migratoria*, an important polyphagous insect causing extensive damage to a large number of crops. Hence, the effect of one of the azasteroids, namely 25-azacholesterol, on growth and development of this insect was studied.

The locusts were reared in the laboratory on one of the host plants, *Sorghum bicolor* (GOEL, 1985). For experimental purposes the freshly moulted fifth instar nymphs were reared on an artificial diet modified from that of DANG *et al.* (1970). The azasteroid was tested at concentrations of 5 to 50 ppm of the wet weight of diet. Suitable control diet was also prepared. The diet was changed daily and excreta removed. Daily observations on the number of adults formed and the number of insects dead were made. The observations were made till 25 days after their transfer to the artificial diet.

The results (Table 1) show that 25-azacholesterol has a profound effect on the developmental process of the locust nymphs. Both the adult emergence and per cent survival, till the termination of the experiment, decreased with an increase in azasterol concentration. In the absence of 25-azacholesterol, 84 per cent of the nymphs moulted into the adults and 80 per cent of the locusts survived upto 25 days, which was the period studied.

TABLE 1. Survival and development of fifth instar nymphs of *L. migratoria* after being transferred from green food to artifical diet containing 25-azacholesterol.

25-aza-chole-sterol (ppm)	No. of insects reared	cumulative mortality % days after transfer					adult emer-gence (%)	survi-[b] val (%)	5th instar duration (days)	insects dead during moulting
		5	10	15	20	25				
0	25	4	20	—	—	—	84	80	7	—
5	21	23.8	42.9	—	—	—	76.2	57.2	5	1
10	23	8.7	30.4	52.2	52.2	60.9	73.9	39.1	5	2
25	27	7.4	51.9	51.9	51.9	59.3	59.3	40.7	7	—
50	25	8	52	60	60	68	56	32	7	2[b]

[a]On the last day of experiment. [b]Insect remained as nymph till the day of completion of experiment.

However, in the presence of 25–azacholesterol, the per cent emergence of adults gradually declined to 56 when 50 ppm of the test compound was added to the diet. Number of days taken by the nymphs to become adult, however, did not show much difference at various concentrations tested. 25-azasteroids have been shown to inhibit larval development of *Diatraea grandiosella* Dyar (AL-IZZI & HOPKINS, 1982). In this insect, however, the larval period was also lengthened significantly at 10 ppm or more of azasteroids and at higher concentrations of 100 to 300 ppm, many larvae did not develop beyond the 2nd or 3rd instar. Similar results were reported in *Spodoptera litura* (KUTHIALA, 1983).

Per cent survival on the day when the experiment was terminated also showed a graded response. It decreased from 80 per cent in the control to 32 per cent at 50 ppm of 25-azacholesterol. A few insects were unable to moult properly and died within the moult at 5 and 10 ppm of azasteroid. No larval-adult intermediates were observed at any of the concentrations used. However, at 50 ppm 8 per cent nymphs failed to moult and remained as nymphs till the end of the experiment. The per cent mortality was found to be maximum at 50 ppm. In *D. grandiosella* also, no precocious moulting or prepupal-pupal intermediates were reported (AL-IZZI & HOPKINS, 1982) as has been shown to occur in the tobacco hornworm (SVOBODA & ROBBINS, 1971) and *Spodoptera litura* (KUTHIALA, 1983).

In case of controls, 20 per cent insects died and the death was within 10 days of their transfer from green food to the artificial diet. At a concentration of 5 ppm, although, mortality increased from 20 to 42.9 per cent, the insects died within 10 days as in the controls. At higher concentrations of azasteriod, mortality was about 7 to 8 per cent on the fifth day of their transfer to the artificial diet. This value showed a sharp rise between 10 to 15 days of their transfer, ranging from 52 to 60 per cent, indicating that 25-azacholesterol exerted its inhibitive action on growth of locust within 10 to 15 days of treatment. However, the exact mechanism by which this compound effects the growth and development in

locust is not understood clearly as yet. It has however, been reported that azasteroids affect the Δ^{22}—and $\Delta^{22, 24}$—sterol reductase enzymes of insects involved in dealkylation process of C_{28} and C_{29} phytosterols and thereby reducing the amount of cholesterol available to the insect. Thus, a study of the mechanism by which locust development is inhibited by azasteroids and similar compounds, and a search for new compounds which may inhibit the utilization of sterols by locust may be very rewarding both scientifically and economically.

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CROSS RESISTANCE PATTERN OF A PIRIMIPHOS-METHYL RESISTANT STRAIN OF *TRIBOLIUM CONFUSUM* DUV. TO SOME INSECTICIDES*

DESH BANDHU AHUJA

Department of Entomology, Agricultural Research Station, (Sukhadia University, Udaipur), Mandore, Jodhpur, India 342 304

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The toxicity of 15 insecticides belonging to chlorinated hydrocarbons, organophosphates, carbamates and synthetic pyrethroids was tested against the adults of the susceptible and resistant strains of *Tribolium confusum* Duv. using direct spray method of bioassay. The pirimiphos-methyl resistance did not extend to any group of insecticides except p', p' DDT. The degree of cross-resistance observed to different insecticides was p', p' DDT × 4.50. lindane × 2.99, iodofenphos × 2, phorate × 2, etrimfos × 1.88, dimethoate × 1.87, chlorpyriphos × 1.80, quinalphos × 1.64, malathion × 1.58, cypermethrin × 1.57, phoxim × 1.57, fenitrothion × 1.48, carbaryl × 1.35, carbofuran × 1.17, and fenvalerate × 1.05.

(Key words: cross resistance, pirimiphos-methyl resistant, *Tribolium confusum,* insecticides)

INTRODUCTION

A pirimiphos-methyl resistant strain of *Tribolium confusum* was developed through laboratory selection for 9 generations (AHUJA,1985). The selected strain was 8.47 times resistant to pirimiphos-methyl as compared to the susceptible strain. Resistance to one insecticide often involves widespread cross-resistance to many other insecticides. Keeping this in view, the cross-resistance pattern of the pirimiphos-methyl resistant strain of *T. confusum* was studied.

MATERIALS AND METHODS

Fifteen insecticides belonging to chlorinated hydrocarbons, organophosphates, carbamates and synthetic pyrethroids were evaluated against the pirimiphos-methyl resistant and the susceptible strains, using direct spray method of bioassay (BHATIA & PRADHAN, 1968). The adult insects (8—10 days old) were starved for 24 hours and then 30 insects were released in each petridish (10 cm diameter). There were 5—6 cocentrations with three replications in one bioassay experiment. Each petridish was sprayed with one ml of freshly prepared emusion except carbaryl where suspension was used, under the potters's tower at a pressure of 0.356 kg per sq cm and later on petridishes were dried, closed and kept in a control room maintained at 30 ± 1°C and 70—80 per cent relative humidity. The amount of benzene and emulsifier were kept constant at 10.0 and 0.6 per cent, respectively. The control petridishes were similarly treated by benzenated emulsified water. All the insecticides were used as technical grade except etrimfos which was used as emulsifiable concentrate. The mortality data taken 72 hours after treatment were subjected to probit analysis (FINNEY, 1971). The resistance to an insecticide was calculated as the ratio of LC_{50} values of the pirimiphos-methyl resistant strain to that of the susceptible strain.

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TABLE 1. Toxicity data of various insecticides to the adults of the pirimiphos-methyl resistant (PMR) and the susceptible(S) strains of *T. confusum*.

Insecticide	S					PMR					ratio of resistance (PMR/S)
	Heterogeneity DF	X^2	regression co-efficient b ± SE	LC_{50}	fiducial limits	Heterogeneity DF	X^2	regression co-efficient b ± SE	LC_{50}	fiducial limits	
P',P'DDT	4	4.8703	12.6584±1.23	0.0083	0.0081–0.0085	4	18.8606*	2.8032±0.21	0 0373	0.0336–0.0413	4.50
Lindane	3	9.5673*	2.9286±0.31	0.0843	0.0763–0.0930	4	17.3982*	1.4127±0.13	0.2520	0.2083–0.3049	2.99
Chlorpyriphos	4	0.9286	5.8225±0.48	0.0015	0.0014–0.0016	3	6.6831	7.8924±0.74	0.0027	0.0024–0.0033	1.80
Dimethoate	4	3.1059	3.4615±0.30	0.0024	0.0022–0.0027	4	10.5375*	3.7319±0.37	0.0045	0.0042–0.0048	1.87
Etrimfos	4	0.3402	4.6595±0.46	0.0017	0.0016–0.0018	4	6.3434	6.4608±0.61	0 0032	0.0031–0.0039	1.88
Fenitrothion	4	5.1982	4.8870±0.46	0.0025	0.0024–0.0027	4	8.0781	8.0781±0.66	0.0037	0.0036–0.0039	1.48
Iodofenphos	4	6.4239	5.8150±0.51	0.0034	0.0032–0.0035	4	6.2021	7.8520±0.64	0.0072	0.0069–0.0074	2.00
Malathion	4	9.3499	6.0432±0.53	0.0060	0.0057–0.0062	4	5.9499	9.0937±0.71	0.0095	0.0073–0.0098	1.58
Phorate	3	0.9349	2.4738±0 30	0.0017	0 0015–0.0019	4	3.3153	5.7639±0.51	0 0034	0.0033–0.0036	2.00
Phoxim	4	2 2616	8.6620±0.77	0.0026	0.0025–0.0026	4	3.1161	4.4415±0.42	0.0041	0.0033–0.0043	1.57
Quinalphos	4	3.9788	3.4113±0.34	0.0025	0.0023–0.0027	4	7.0947	6.4184±0.56	0. 040	0.0038–0.0041	1.64
Carbaryl	4	1.1730	5.8329±0.47	0.0984	0.0039–0.1033	4	3.2307	5.8420±0.59	0.1326	0.1246–0.1391	1.35
Carbofuran	3	2.4383	7.4024±0.68	0.0035	0.0034–0.0036	4	4.8764	6.3644±0.53	0.0041	0.0039–0.0043	1.17
Cypermethrin	4	6.1441	6.4448±0.61	0.0014	0.0013–0.0015	4	5.4014	5.1117±0.45	0.0022	0.0021–0.0024	1.57
Fenvalerate	4	3.8635	9.3762±0.93	0.0060	0.0058–0.0061	4	5.0424	9.1394±0.82	0.0063	0.0061–0.0065	1.05

*Heterogeneous at $p = 0.05$.

RESULTS AND DISCUSSION

The data presented in Table 1 revealed that the selection for pirimiphos-methyl resistance resulted into increase in LC_{50} values for the resistant strain over the susceptible strain. The degree of resistance observed to different insecticides was p', p' DDT × 4.50, lindane × 2.99, iodofenphos × 2, phorate × 2, etrimfos × 1.88, dimethoate × 1.87, chlorpyriphos × 1.80, quinalphos × 1.64, malathion × 1.58, cypermethrin × 1.57, phoxim × 1.57, fenitrothion × 1.48, carbaryl × 1.35, carbofuran × 1.17 and fenzalerate × 1.05. Similar studies with 18.72 times pirimiphos-methyl resistant strain of *Tribolium castaneum* had showncross-resistance to a wide range of insecticides namely lindane × 13.45, carbaryl × 9.80 p', p' DDT × 8.60, malathion × 6.86, dimethoate × 6.80, quinalphos × 6.24, phoxim × 3.58, carbofuran × 3.50, cypermethrin × 3.11, fenitrothion × 2.68, chlorpyriphos × 2.67, phorate × 2.48, iodofenphos × 2.43, etrimfos × 2.33, except fenvalerate × 1.14 (AHUJA, 1986). The differences may be due to presence of low level of resistance (8.45) in *T. confusum* to pirimphos-methyl as compared to high level of resistance (18.72) in *T. castumeum*. BHATIA & PRADHAN (1972) showed that there was no cross-resistance to malathion (1.0 ×) in 12.45 × lindane resistant strain of *T. castaneum*, but increase in lindane resistance in this strain to 45.11 times resulted into 4.09 times resistance to malathion (JITENDAR KUMAR & BHATIA, 1981).

In general, mechanism of selection acquired after selection with one insecticide endows the insect with the ability to resist a wide variety of insecticides. Cross-resistance to a wide range of insecticides belonging to different groups was demonstrated in malathion resistant strains of *T. castaneum* (CHAMP & CAMPBELL-BROWN, 1970; BENGSTON *et al.*, 1975; LLOYD *et al.*, 1976; LLOYD & RUCZKOWSKI, 1980), *Sitophilus oryzae* (BANSODE & BHATIA, 1978), *Oryzaephilus mercator* (DYTE & FORSTER, 1973), lindane resistant *T. castaneum* (BHATIA & PRADHAN, 1972; JITENDAR KUMAR & BHATIA, 1981; BARWAL & KALRA, 1982), DDT and lindane resistant *S. zeamais* (MELLO, 1972), pyrethin resistant *S. granarius* (PARKIN & LLOYD, 1963; LLOYD, 1973; PRICKETT, 1980). However, there are instances where development of resistance to an insecticide did not show any cross-resistance to both intra and inter group of insecticides. ZETTLER & ZONES (1977), WILLIAMS *et al.* (1978), and BANSODE & CAMPBELL (1979) detected no cross-resistance to pirimiphos-methyl and several different insecticides when tested against malathion resistant adults of *T. castaneum*. No cross resistance was observed in any of three malathion resistant strains of *T. castaneum* and one malathion resistant strain of *T. confusum* to methoprene and neoprene (AMOS *et al.*, 1977). A malathion resistant strain of *Plodia interpunctella* did not show cross resistance to other organophosphates and synthetic juvenile hormones (LA-HUE, 1969; ZETTLER, 1974; SILHACEK *et al.*, 1976).

In the present investigation, the degree of cross resistance shown to various insecticides except p',p' DDT was low but the results still suggested that the development of resistance to pirimiphos-methyl may render many other insecticides useless for insect control, as observed in earlier studies (AHUJA, 1986).

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CONTROL OF THE SAPLING BORER, *SAHYADRASSUS MALABARICUS* (LEPIDOPTERA, HEPIALIDAE) IN FOREST PLANTATIONS[1]

K. S. S. NAIR

Division of Entomology, Kerala Forest Research Institute, Peechi, India 680 653

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A simple method was developed to control the larva of *Sahyadrassus malabaricus* which tunnels into the stem of forest tree saplings. The tunnel mouth and the surrounding area is covered by a mesh-work of bark, wood and frass particles spun together with silk. When the cover is removed, the larva rebuilds it overnight using wood particles gnawed out from the region. This behaviour was made use of to kill the larva by superficial spot application of insecticide after removing the cover. HCH, lindane, carbaryl and 'sevimol' were tested at 0.5% (ai.) concentration and quinalphos at 0.125%; quinalphos alone gave complete control.

(Key words: Sahyadrassus malabaricus, sapling borer, quinalphos, Hepialidae, behaviour)

INTRODUCTION

The life history, some aspects of ecology and the pest status of the sapling borer, *Sahyadrassus malabaricus* (Moor) (Lepidoptera, Hepialidae) were studied earlier (NAIR, 1985). It was found that control of the borer is necessary for raising successful plantations of some forest tree species. Methods recommended in the past for control of this or related species (KALSHOVEN, 1924; SONAN, 1938; BEESON, 1941) included killing the larva physically by inserting a twig or sharp wire into the borer hole, plugging the borer hole with tar, or injecting an insecticide into the borer hole by means of a syringe. There are no reports on the effectiveness of any of these methods. The behaviour of the larva (NAIR, 1985) indicated a new possible method of control, which was field-tested in this study.

The tunnel mouth and the surrounding feeding area is covered by a thick mat of bark, wood and frass particles held together by silk, which has been termed a 'particle-mat-cover' (PMC) (NAIR, 1985). If the PMC is removed, the first reaction of the larva is to rebuild it with fresh particles of bark and wood gnawed out from the vicinity of the tunnel mouth. If an insecticide is applied over the region after pulling off the PMC, the larva may die by coming in contact with the insecticide while rebuilding the PMC and / or by ingesting the treated bark.

MATERIALS AND METHODS

In the selected plantations of teak *(Tectona grandis)* or *Trema orientalis* the infested saplings were marked with aluminium tags. The PMC was pulled off and trees in which it was rebuilt, indicating the presence of healthy larvae, were selected for the experiment. The rebuilt PMC was again pulled off and the insecticide was liberally brushed on the area using a 4 cm paint brush. In control (untreated) saplings water was applied in the same manner. Five trials were conducted at different localities between 1979 and 1982 and 8 to 50 saplings

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were used per treatment, depending on the availability of infested saplings. The insecticides used were commercial dust formulations of HCH and carbaryl and EC formulations of lindane, sevimol (carbaryl plus molasses) and quinalphos (Ekalux). A sticker–spreader was added in the emulsions. In addition, tar concentrate was tested. In some experiments, the insecticide was mixed with a preparation consisting of 50 g of 'maida' (fine wheat flour), 200 g of jaggery (cane sugar molasses) and 200 ml of glycerol in one litre of water. Maida and jaggery were mixed with water and heated to boiling. When the slurry began to thicken, the container was taken off the flame, glycerol was added with stirring and the mixture was allowed to cool to room temperature. The desired quantity of insecticide was then added and mixed thoroghly to obtain a slow-drying sticky preparation of the insecticide.

RESULTS

Table 1 summarises the results of the six experiments. HCH, at 0.5% a i, did not cause significant mortality in three trials. Lindane (HCH), carbaryl, and sevimol, all at 0.5% a i as well as tar concentrate caused significant mortality but did not give complete protection. When treated with tar, most larvae rebuilt the PMC close to the inner edge of the tunnel mouth, avoiding the treated area. Later, as tar dried up, some larvae extended the PMC to the treated area. Some made unsuccessful attempt to open up an alternative hole either close to the original opening or at the lower end of the tunnel. In contrast to all other chemicals, quinalphos at 0.125% a i gave complete control in one trial. Its effectiveness was further confirmed in subsequent trials carried out on larvae rehabilitated on saplings of *Trema orientalis*, as well as in routine control

TABLE 1. Effect of insecticides on *Sahyadrassus malabaricus* larvae when applied at the tunnel mouth.

insecticide & % concentration (a i)	percentage mortality					
	Parambikulam 1979[a]	Kothamangalam 1980	Athirapally 1980	Vazhachal 1980	Vazhachal 1981	Arippa 1982
	(17)[b]	(22–24)	(12–19)	(21–25)	(50)	(8)
Nil (Control)	41	17	16	13	0	0
HCH (BHC) (0.5)	—	8	36	24	—	—
Lindane (0.5)	88[x]	—	71[x]	—	—	—
Carbaryl (0.5 or 1.0)[c]	—	59[x]	60[x]	80[x]	26[x]	—
Carbaryl (1.0) with adjuvants	—	—	—	—	88[y]	—
Sevimol (0.5)	94[x]	—	83[x]	—	—	—
Quinalphos (0.125)	—	—	—	—	—	100[x]
Quinalphos 0.125) with adjuvants	—	—	—	—	—	100[x]
Tar concentrate	—	—	57[x]	—	—	—

a, Place and year of field trial; b. No. of larvae receiving each treatment; c, 1.0% was used only in the 1981 trial x, These figures (actual numbers were used for the chisquare tests) differed significantly from the respective controls at $p<0.01$, except in the case of tar concentrate where the difference was significant only at $p<0.05$. y, This value differed from that superscribed by x in the same column at $p<0.01$.

operations on infested saplings in a teak seed orchard.

Addition of the experimental adjuvants to carbaryl increased the percentage of mortality significantly (Table 1), but did not cause total mortality. On the other hand, quinalphos caused total mortality even without the adjuvants. However, addition of adjuvants to quinalphos caused quicker death as indicated by failure of the larvae to rebuild the PMC. In the absence of adjuvants, most larvae died only after they had rebuilt the PMC.

In preliminary trials conducted on larvae rehabilitated on *T. orientalis* saplings, the commercial preparation, "stikkem special" (Seabright Enterprises, USA) applied over the tunnel mouth area failed to trap the larva.

DISCUSSION

Among the insecticides tested, quinalphos was the only one that caused 100% mortality. Although death was quicker when adjuvants were added, from the practical point of view, it is more convenient to use the insecticide alone. Quinalphos has dual action as a contact and stomach insecticide (WORTHING, 1979) and its greater effectiveness over others is probably due to added stomach action through consumption of treated bark.

The method of insecticide application suggested in this study is simple and effective. In addition, as the insecticide is brushed over a small area of the stem of infested saplings, environmental contamination is neligible. Although injection of an insecticide into the tunnel as well as tar plugging, which have been suggested in the literature, may prove effective, they are cumbersome. Physical killing with a wire probe, also suggested in the literature, is not feasible becacuse it is difficult to insert the wire through the sharply bent top portion of the tunnel.

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INVESTIGATIONS ON THE HOST-SPECIFICITY AND DAMAGE POTENTIAL OF *ZYGOGRAMMA BICOLORATA* PALLISTER (COLEOPTERA : CHRYSOMELIDAE) INTRODUCED INTO INDIA FOR THE BIOLOGICAL CONTROL OF *PARTHENIUM HYSTEROPHORUS*[1]

K. P. JAYANTH & SUDHA NAGARKATTI[2]

All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds, Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bangalore, India 560 089

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Parthenium hysterophorus L. of South and Central American origin, is a serious weed in India, covering about 5 million ha of land. *Zygogramma bicolorata* Pallister was introduced from Mexico in 1983 and host-specificity tests were carried out under quarantine conditions with 40 plants belonging to 27 families. Based on these studies which proved that the insect is capable of feeding and reproducing only on *Parthenium*, field cage studies were initiated which showed that *Z. bicolorata* is able to breed under Bangalore conditions and cause extensive damage to *Parthenium* plants.

(Key words: Parthenium hysterophorus, Zygogramma bicolorata, biological control)

INTRODUCTION

The annual composite weed *Parthenium hysterophorus* L., native to the Americas, was first observed in India in 1956 and has since spread virtually all over the country covering approximately 5 million ha of land (GIDWANI, 1975). Not only does it infest range and waste lands but it also invades cultivated fields and poses a threat to crops such as cereals, vegetables, oil seeds, etc. KANCHAN & JAYACHANDRA (1979, 1980) and MOHANDAS (1981) have demonstrated the allelopathic effects of *P. hysterophorus* caused by exudation of inhibitors through the roots as well as leaching of inhibitors from the aerial vegetative parts and the inhibitory action of trichomes from the leaves when they settle on the leaves of other plants. MOHANDAS (1981) has also described the inhibition of fruit set in crops like tomato, brinjal, beans and capsicum when pollen grains of *Parthenium* are artificially dusted on the stigmatic surfaces. Clusters of pollen, when placed on floral parts of plants such as maize cause 50% reduction in grain filling. The health hazards caused by *Parthenium* are also well known and there is considerable documentation on contact dermatitis and rhinitis caused by the weed (TOWERS *et al.*, 1977).

In India enormous amounts of money are being spent on manual removal of

[1]Contribution No 117/85 of Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bangal ore, India-560 089.

[2]Present Address: North Carolina Dept. of Agriculture, 11130 Blue Heron Drive, Pineville, N C 28134, USA.

the weed, despite which it is spreading. The cost of herbicidal control would be prohibitive considering the vast tracts of infested waste lands. Although a number of indigenous insects have successfully colonized *Parthenium* in India (CHAR *et al*, 1975; KUMAR *et al*. 1979), none of these have been able to control the weed. Moreover, most of the insects are economic pests of crops and their use to control the weed cannot be advocated.

Surveys carried out by the Department of Lands, Queensland, Australia, in collaboration with the Commonwealth Institute of Biological Control (CIBC) in Mexico and South America resulted in the discovery of a large array of insects (BENNETT, 1976). In March 1983 permission was obtained for importing *Zygogramma bicolorata* Pallister (Coleoptera : Curculionidae), one of the insects identified in the above study. The present paper describes laboratory rearing, host-specificity tests and field cage studies carried out in India with *Z. bicolorata*.

MATERIALS AND METHODS

The shipment of *Z. bicolorata* was received from the CIBC Mexican sub-station in April 1983 and held in quarantine until completion of host-specificity tests. The adult beetles received in cages and jars with potted *Parthenium* plants or bouquets bearing fresh leaves. The larvae hatching from eggs that were laid on the leaves were provided with a continuous supply of fresh leaves. Full grown larvae were trasferred to jars containing a 5 cm layer of fine sterile sand to facilitate pupation.

Feeding and oviposition tests were carried out by releasing 5 adults each on bouquets of test plants held in 14 × 12 cm clear plastic jars provided with screened windows for aeration. The adults were confined with the test plants until they died. Feeding tests were also carried out with 10 day old larvae by releasing 5 larvae as in the previous tests. These tests were replicated 3 times.

In September 1982 permission of the Plant Protection Adviser to the Government of India was obtained for conducting limited field trials in Bangalore. In October 1983, field cage studies were initiated to determine the damage potential of *Z. bicolorata* against *P. hysterophorus*. For this purpose, a walk-in field cage was used, covered on all sides with nylon screen and supported by a metal frame. The cage was placed over a natural pure stand of *Parthenium*. The cage covered an area of 1.8m² and enclosed about 100 plants measuring between 20 and 30 cm in height. Thirty laboratory reared adults (males and females) of *Z. bicolorata* were released in the cage and feeding, oviposition, emergence of adults of the following generation and time taken for complete destruction (defoliation) of the plants were closely monitored.

RESULTS AND DISCUSSION

Host-specificity

Amongst the 40 plants tested, neither adult feeding, oviposition nor larval feeding was observed on 37 (Table 1). Adult *Z. bicolorata* that had fed on *Parthenium* for a week and then transferred to garlic (*Allium sativum*) laid 30 eggs one day on the garlic plant as well as on the lid of the jar. Egg laying was not observed on subsequent days and the larvae on hatching did not feed on garlic and died within two days. Freshly emerged adults which had not fed on *Parthenium* failed to lay eggs on garlic, ruling out the possibility of garlic being an acceptable host.

Slight nibbling by adults was observed on jasmine (*Jasminum grandiflorum*) and niger (*Guizotia abyssinica*). In the case of jasmine, nibbling was observed only for the first 10 days. Although the adults survived for an additional 34 days, neither feeding nor egg-laying were observed and larval feeding tests also gave negative results. Nibbling by adults on niger was observed only for the first 6 days in

TABLE 1. Test plants on which feeding or egg laying by *Z. bicolorata* were not observed at Bangalore.

Sl. no.	Family	Species	Common name	Max. no. of days survived	
				10 days larvae	adults
1	Amaryllidaceae	*Polyanthes tuberosa*	Tube rose	6	10
2	Anacardiaceae	*Anacardium occidentale*	Cashew	6	39
3	Araceae	*Colocasia esculenta*	Arvi	5	19
4	,,	*Amorphophallus* sp.	Yam	6	11
5	Compositae	*Lactuca sativa*	Lecttuce	6	20
6	,,	*Helianthus annuus*	Sunflower	5	15
7	,,	*Cosmos bipinnatus*	—	5	18
8	,,	*Dahlia* sp.	—	6	27
9	,,	*Coreopsis* sp.	—	5	36
10	,,	*Aster laevis*	Michaelmas daisy	6	30
11	,,	*Callistephus chinensis*	Aster	13	25
12	,,	*Solidago* sp.	Goldenrod	6	30
13	,,	*Tagetes orecta*	Marigold	8	15
14	,,	*Gazania rigors*	Gerbera	8	38
15	,,	*Calendula* sp.	—	7	26
16	,,	*Chrysanthemum* sp.	—	6	40
17	,,	*Carthamus tinctorius*	Safflower	5	11
18	Cruciferae	*Brassica nigra*	Mustard	5	13
19	,,	*Raphanus sativus*	Radish	6	13
20	Cucurbitaceae	*Citrullus vulgaris*	Watermelon	5	17
21	Euphorbiaceae	*Ricinus communis*	Castor	6	17
22	Graminaceae	*Oryza sativa*	Paddy	8	15
23	Labiatae	*Mentha arvensis*	Mint	5	13
24	Leguminosae	*Pisum sativum*	Pea	10	13
25	,,	*Vigna sinensis*	Cowpea	6	44
26	Malvaceae	*Abelmoschus esculentus*	Bhendi	6	42
27	Moraceae	*Morus alba*	Mulberry	6	20
28	Myrtaceae	*Psidium guajava*	Guava	8	17
29	Palmaceae	*Cocos nucifera*	Coconut	4	12
30	Piperaceae	*Piper nigrum*	Pepper	5	13
31	Punicaceae	*Punica granatum*	Pomegranate	8	20
32	Rutaceae	*Murraya exotica*	Curry leaf	8	12
33	Sapotaceae	*Achras zapota*	Sapota	5	13
34	Solanaceae	*Solanum melongena*	Brinjal	8	22
35	Umbelliferae	*Coriandrum*	Coriander	6	21
36	Verbenaceae	*Tectona grandis*	Teak	5	20
37	Zingiberaceae	*Curcuma longa*	Turmeric	6	15

one of the three replicates. Here again no further feeding and egg-laying were observed during the remaining 12 days that the adults were alive. Larvae of *Z. bicolorata* also did not accept niger.

In multiple choice tests, when jasmine, niger and garlic were provided in a cage along with *Parthenium*, egg-laying and larval feeding were observed only on *Parthenium*. Adults of *Z. bicolorata* survived for a maximum of 138 days on *Parthenium* and laid an average of 1802.6 eggs (range : 452–2675). The eggs hatched in 4—6 days and larval and pupal periods lasted 14—16 and 8–10 days and 8—10 days respectively at 26 ± 2°C and 40 to 60% RH. Eggs were laid on leaves and full grown larvae entered the soil and pupatad forming cells.

A series of multiple-choice tests involving Compositae were carried out by Mc CLAY (1980). The plants tested by him were : *Ambrosia psilostachya*, *Bidens pilosa*, *Carthamus tinctorius*, *Chrysanthemum sinensis*, *Cichorium intybus*, *Coreopsis* sp., *Cosmos* sp., *Dahlia* sp., *Helianthus annus*, *Lactuca sativa*, *P. argentatum*, *P. confertum*, *Rudbeckia* sp. and *Zinnia* sp. He concluded that only *P. hysterophorus* (and possibly *P. confertum)* could support the insect. Similarly McFADYEN (1980) carried out tests with 51 species of plants belonging to 27 families and concluded that *Z. bicolorata* is capable of multiplying only on *P. hysterophorus* and that occasional feeding might occur on *Ambrosia* spp. which are weeds. Detailed studies were carried out with 11 varieties of sunflower, all giving negative results (McFADYEN 1981).

Field cage studies :

In the present study, *Z. bicolorata* adults laid a large number of eggs on the *Parthenium* plants enclosed within the field cage. The young larvae were observed to congregate on the terminal and axillary buds and cause heavy damage leading to stunted growth and reduced flower production. Older larvae fed on peripheral leaves. In plants which had just started producing flowers, further production was completely suppressed and no flowers were produced by smaller plants. Within four weeks after releasing the insects in the field cage, all the plants were completely defoliated. Emergence of adults started from the fifth week onwards and continued for 2 weeks. More than 500 adults could be collected from one field cage.

The results of this study clearly demonstrated that *Z. bicolorata* is capable of breeding under field conditions at Bangalore and can cause considerale damage to *Parthenium* plants. However, it may take many years for the insect to build up to damaging proportions and overtake the weed under field conditions. It is not known how successfully the insect would survive the dry period from December to May when mature *Parthenium* plants with abundant foliage are scarce (althougth small plants do occur on sides of ditches and drains where some moisture is present). Also, it is not yet known whether the insect would be subject to parasitism and predation by local natural enemies of allied species of Chrysomelidae.

In Australia *Z. bicolorata* has established in the field along with a stem-boring weevil, *Listronotus setosipennis* (Hustache) and a stem galling moth *Epiblema strenuana* (Walker) only the last is having an impact on the weed (McFADYEN, (1984). It was further reported that the population of *Z. bicolorata* appears to be restricted by poor survival

under conditions of delayed rain as is common in Central Queensland. However, it would not be correct to assume that *Z. bicolorata* will be incapable of giving the desired results under Indian conditions. In the U S S R, KOVALEV & MEDVEDEV (1983) followed the introduction of *Z. suturalis* F. in 1978 from Canada and USA for the control of *Ambrosia artemisifolia* L & *A. psilostachya* D C. By the end of the summer of 1981 the insect was found to have spread over 200 ha. Overwintering beetles were reported to feed on *Ambrosia* germinants and shoots and as food deficiency increased, they even ate stalks of the germinants. An interesting fact reported by these authors is that *Z. suturalis* has relatively low fecundity and a tendency to form foci of massive reproduction in which the food plants are completely destroyed, after which the population moves to neighbouring sectors. Additionally, the toxic hemolymph of the chrysomelid protects it from attack of parasites and predators.

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INFLUENCE OF WEATHER FACTORS ON THE CATCHES OF MOTHS OF GROUNDNUT LEAF MINER *APROAEREMA MODICELLA* DEVENTER IN THE LIGHT TRAP

G. LOGISWARAN[1] & M. MOHANASUNDARAM

Department of Agricultural Entomology, Tamilnadu Agricultural University, Coimbatore, India

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Relationship between the light trap catches of groundnut leaf miner *Aproaerema modicella* Deventer and weather at Tindivanum during 1983—1984 was computed at 15 and 90 days interval. A negative association of the catches with maximum temperature, minimum temperature and wind velocity and positiva association with total rainfall, morning and evening relative humidity was observed. Correlation with variables involving 90 days interval gave more significant association than those involving 15 days interval. Multiple regression equations were fitted to predict the number of moths caught in the light trap. Wind velocity exerted a significant negative association in both 15 and 90 days interval, the partial regression coefficients being — 345.132 and — 3504.030 respectively.

(Key words: weather fators, moth catches, groundnut leaf miner, *Aproaerema modicella)*

INTRODUCTION

The leaf miner *Aproaerema modicella* Deventer is a serious pest of groundnut and soybean. The infestation of the crop starts from 15 to 20th day of sowing and continues nearly up to the harvesting stage. Pod yeild losses to an extent of 49 to 56 per cent are attributed to the attack by this pest (TEJKUMAR, 1980). Besides Tamilnadu, this pest is also a menace in the States of Karnataka, Andhra Pradesh, Maharashtra, Orissa, Gujarat, Madhya Pradesh, Rajasthan and Punjab (MOHAMMAD, 1981). In Tamilnadu, the rainfed crop (July to October) suffers more damage than the irrigated crop (January to April). Based on the moth catches in the light trap LOGISWARAN & MADHAVA RAO (1985) reported that the pest was more adundant with five brood emergences during the rainfed season than in irrigated season wherein two brood emergences only were observed. Investigations were hence carried out to elucidate the influence of weather factors on the catches of moths in the light trap, and the findings reported in this paper,

MATERIALS AND METHODS

a. *Light trap catches*: A light trap with 200 watts blub installed at the Oil Seeds Experiment Station, Tindivanum was operated from 6 pm to 6 am throughout the study period. The number of moths caught in the trap were recorded daily.

b. *Weather factors:* All the data except evening relative humidity were recorded at 0710 hour. The evening relative humidity was recorded at 1410 hour.

The total number of moths caught in a period of one year at 15 days interval from 11.3.1983 to 5.3.1984 and the mean weather parameters for the above period were calculated and multiple regression analysis was made using light trap catches as dependent variable (Y)

[1]Oil seeds Experiment Station, Tindivanum.

and each of the weather parameters as independent variable (x) (PANSE & SUKHATME 1967).

In another study, twenty four sowings of groundnut were taken up for a one year period at 15 days intervals from 20.12.1982 to 1.12.1983. The total number of moths caught in a period of 90 days ie., 5 days after sowing and 10 days prior to harvest of each crop and the mean weather parameters for the above period were also calculated and multiple regression analysis was done as stated above.

RESULTS AND DISCUSSION

The correlation matrix showing the relationship between the light trap catches and weather factors for 15 and 90 days interval are furnished in Tables 1 and 2 respectively. In both the cases, the number of moths caught in the light trap exerted a negative association with maximum temperature, minimum temperature and wind velocity and positive association

TABLE 1. Correlation matrix of the relationship between light trap catches (Y) and weather parameters (n = 24) (Data computed at 15 days interval).

variables	X_1	X_2	X_3	X_4	X_5	X_6
Light trap catches	−0.277NS	−0.354NS	−0.577xx	0.185NS	0.364NS	0.357NS
X_1 Maximum temperature (°C)		0.961xx	0.317NS	−0.542xx	−0.800xx	−0.929xx
X_2 Minimum temperature (°C)			0.444x	−0 393NS	−0.765xx	−0.848xx
X_3 Wind velocity (km/hr)				−0.112NS	−0.454x	−0.244NS
X_4 Total rainfall (mm)					0.594xx	0.696xx
X_5 Morning RH (%)						0.833xx
X_6 Evening RH (%						

x significant at $p = 0.05$ xx significant at $p = 0.01$ N S not sinificant

TABLE 2. Correlation matrix of the relationship between light trap catches (Y) and weather parameters (n = 24)
(Data computed at 90 days interval)

variables	X_1	X_2	X_3	X_4	X_5	X_6
Light trap catches (Y)	−0.475x	−0.443x	−0.416x	0.675xx	0.469x	0.586xx
X_1 Maximum temperature (°C)		0.977xx	0.493x	−0.690xx	−0.884xx	−0.978xx
X_2 Minimum temperature (°C)			0.622xx	−0.574xx	−0.915xx	−0.958xx
X_3 Wind velocity (km/hr)				−0.114NS	−0.712xx	−0.510x
X_4 Total rainfall (mm)					0.624xx	0.770xx
X_5 Morning R H (%)						0.894xx
X_6 Evening RH (%)						

x significant at $p = 0.05$ xx significant at $p = 0.01$ NS not significant.

TABLE 3. Multiple regression analysis of the light trap catches (Y) and weather parameters (n = 24).
(Data computed at 15 days interval)

variables	mean ($\bar{x}$)	partial regression coefficient (b)	SE_b	t
X_1 Maximum temperature (°C)	33.42	510.868	292.536	1.746NS
X_2 Minimum temperature (°C)	22.79	−324.477	348.953	−0.930NS
X_3 Wind velocity (km/hr)	8.04	−346.132	149.885	−2.309x
X_4 Total rainfall (mm)	80.61	− 1.068	2.638	−0.405NS
X_5 Morning R H (%)	81.16	− 28.232	43.124	−0.655NS
X_6 Evening R H (%)	56.55	115.526	47.556	2.429x
Constant term a = − 10324.207			R^2 = 0.530x	
Mean of the dependant variable (Y) = 730.5				

x significant at $p = 0.05$ NS not significant

TABLE 4. Multiple regression analysis of the light trap catches (Y) and weather parameters (n = 24)
(Data computed at 90 interval)

variable	mean ($\bar{x}$)	partial regression co-effieient (b)	SE_b	t
X_1 Maximum temperature (°C)	33.72	497.846	1530.109	0.325NS
X_2 Minimum temperature (°C)	22.82	1300.131	3332.080	0.390NS
X_3 Wind velocity (km/hr)	7.95	−3504.030	1048.300	−3.343xx
X_4 Total rainfall (mm)	407.85	8.515	7.874	1.081NS
X_5 Morning RH (%)	80.78	− 707.786	364.113	−1.944NS
X_6 Evening RH (%)	55.83	603.332	563.551	1.070NS
Constant term a = 5127.108			R^2 = 0.753xx	
Mean of ths dependant variable (Y) = 3717.917				

xx significant at $p = 0.01$ NS not significant.

with total rainfall, morning and evening relative humidity. However, in the case of the data computed at 15 days interval the association was significant only in the case of wind velocity. But in the case of the data computed at 90 days interval the association was significant with all the weather parameters.

The results of the multiple regression analysis in respect of the data computed for 15 days interval (Table 3) the R^2

value was 0.530 (significant at $p = 0.05$) while it was 0.753 (significant at $p = 0.01$) in the case of the data computed for 90 days interval (Table 4) showing that the correlation with the variables involving 90 days interval gave more significant associations. In the case of the data computed for 15 days interval, the multiple regression equation fitted with weather factors to predict the number of moths caught in the light trap was $Y = -10324.207 + 510.868\ x_1 - 324.77x_2 - 346.132\ x_3 - 1.068\ x_4 - 28.232\ x_5 + 115.526\ x_6$, indicating that an increase of one km/hour in wind velocity would lead to a decrease of 324 moths caught in the light trap while an increase of one per cent in the evening relative humidity would lead to an increase of 116 moths caught in the light trap. In the case of the data computed for 90 days interval, the multiple regression equation fitted with weather factors to predict the number of moths caught in the light trap was $Y = 5127.108 + 497.186x_1 + 1300.31\ x_2 - 3504.030x_3 + 8.515\ x_4 - 707.786x_5 + 603.332\ x_6$, indicating that an increase of one km/hour in wind velocity would lead to a decrease of 3504 moths caught in the light trap.

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CHANGES IN THE PROTEIN CONCENTRATION OF THE HAEMOLYMPH IN RELATION TO MNC-CAUTERY, ALLATECTOMY AND OVARIECTOMY IN THE FIELD CRICKET *PLEBEIOGRYLLUS GUTTIVENTRIS* (WALK.) (ORTHOPTERA : GRYLLIDAE)[1]

K. RAMASAMY & N. RAMALINGAM

Department of Zoology, Annamalai University, Annamalainagar, Tamilnadu, India 608 002

(Received 23 September 1985)

The changes in the haemolymph protein content were examined in the MNC-cauterized, allatectomised, ovariectomised, and control insects. The protein content of the haemolymph significantly decreased in the MNC-cauterized and allatectomised female insects. No protein granules were noticed in the terminal oocytes of these experimental insects. The findings reveal that both the MNC and CA are essential for protein synthesis. After ovariectomy the haemolymph protein content significantly increased indicating that in the absence of the ovary the synthesised protein through MNC and CA principles remains unutilized.

(Key words: median neurosecretory cells, corpora allata, protein synthesis, haemolymph, *Plebeiogryllus guttiventris)*

INTRODUCTION

Studies on haemolymph protein concentration have shown that distinct fluctuations in the concentration of haemolymph proteins are associated with oocyte maturation in insects (HILL, 1962; SCHEURER, 1969; ELLIOTT & GILLOTT, 1977; KAMALAKANNAN, 1977). These proteins have been found to be synthesised in the fat body (ORR, 1964) and released into the haemolymph from where they are sequestered by the oocytes (TELFER, 1961; ENGELMANN & PENNEY 1966). Regarding the endocrine control of the synthesis of protein, SLAMA (1964) has reported that in *Pyrrhocoris apterus* the corpora allata regulate the utilization of protein by ovaries and not the synthesis of protein. Likewise corpora allata have been shown to be responsible for the uptake of haemolymph proteins into the oocytes (PFEIFFER, 1945; HILL, 1962; MCCAFFERY, 1976). WILKENS (1969) and CLIFT (1971) have attributed a similar function to the neurosecretory cells of the brain. In contrast, it has been reported for *Rhodnius prolixus* (COLES, 1965), *Nauphoeta cinerea* (WILHELM & LUSCHER , 1974) and *Odontopus varicornis* (KAMALAKANNAN, 1977) that the protein synthesis and utilization of yolk protein are cotrolled by corpora allata.

Further, the protein content of the haemolymph has been shown to decrease after allatectomy in *Leucophaea maderae* (ENGELMANN & PENNEY, 1966) and *Rhodnius prolixus* (PRATT & DAVEY, 1972)

[1] From the thesis submitted by the first author to Annamalai University in partial fulfilment of the requirements of the degree of Doctor of Philosophy.

while its level has increased in *Schistocerca gregaria* (HIGHNAM *et al.*, 1963), *Locusta migratoria migratoroides* (STRONG, 1967) and *Leptinotarsa decemlineata* (DE LOOF & DE WILDE, 1970).

Concerning the role of neurosecretory cells of the brain in protein metabolism, HILL (1962) has demonstrated for *Schistocerca gregaria* that the synthesis of haemolymph protein is stimulated by the neuroendocrine factors from the brain. The median neurosecretory cells seem to be essential for the synthesis of haemolymph protein in *Calliphora erythrocephala* (THOMSEN & MOLLER, 1963). According to JALAJA & PRABHU (1971) the median neurosecretory cells are involved in the synthesis of protein while the corpora allata are essential for the uptake of proteins into the oocytes. On the other hand, in *Leucophaea maderae* (SCHEURER, 1969; WYSS-HUBER & LUSCHER, 1972), *Leptinotarsa decemlineata* (DE LOOF & DE WILDE, 1970), *Rhodnius prolixus* (BAEHR, 1974) and *Melonoplus sanguinipes* (ELLIOTT & GILLOTT, 1977, 1978) the synthesis of protein has been shown to be influenced by both the median neurosecretory cells and corpora allata. To understand the role of the median neurosecretory cells and corpora allata in protein metabolism, the total protein content of the haemolymph has been examined in control and experimental females.

MATERIALS AND METHODS

Rearing

The adult females of *P. guttiventris* collected from field were reared in bottles (16× 9 × 7 cm) at the room temperature of 28±2°C and a 12 h light: 12 h dark photoperiod. The insects were fed daily with powdered pea-seeds, pumpkin and cucumber. The insect bottles were cleaned properly, removing the faecal pellets and other waste materials. The insects thrived well on the diet mentioned above and reproduced normally. After oviposition, the insects were transferred to another bottle and were fed with the same diet. Thus, a continuous culture was maintained.

Determination of protein content

The total protein content of the haemolymph was estimated employing the method of LOWRY *et al.* (1951). Bovine serum albumin was used to construct the standard curve. Estimations of the protein concentration in the haemolymph of MNC-cauterized, allatectomised, ovariectomised and control insects were made. The operation procedures followed in the present work are described below.

Thermocautery of median neurosecretory cells

Newly emerged adult females (8 hr after emergence) were collected and anaesthetized with ether. A small square of head cuticle was cut in the frons and the cephalic air sacs and associated fat bodies were removed. Excess haemolymph in the wound region of protocerebrum was blotted away. A heated needle was carefully applied to the pars intercerebralis part of the brain through the cut region in order to burn only the median neurosecretory cells. Then, a few crystals of streptomycin sulphate were added to the cauterized region, the folded cuticle was replaced and the wound was sealed with molten paraffin wax. Sham-cautery was done in a similar manner as described above except that the MNC were not burned.

Allatectomy

Allatectomy was performed on adult insects after 8 hours of imaginal ecdysis. The insect was anaesthetized with ether and fastened to a wax dish with the neck stretched. The cervical membrane was incised and the corpora allata were removed with a pair of watch-makers forceps, taking care not to damage either corpora cardiaca or oesophagus. Then, a few crystals of streptomycin sulphate were added and the wound was sealed with molten paraffin wax. Operated insects were always observed after treatment to ensure that they feed normally. The success of allatectomy was checked by histological methods. Sham-operation was done exactly as described above but the gland was left intact.

Ovariectomy

The adult females were ovariectomised 8 hours after the imaginal ecdysis. They were anaesthetized with ether. An incision was

made on the abdomen at the level of each ovary and it was removed under binocular microscope. Each ovary was pulled out along with its tracheal bunch by means of watch-makers' forceps previously sterilized in rectified spirit. A few crystals of streptomycin sulphate were added and the incisions were closed with molten paraffin wax. Sham-ovariectomy was done exactly in a similar manner as deseribed above but a piece of fat body, instead of ovary, was removed.

RESULTS

The protein content in the haemolymph of *Plebeiogryllus guttiventris* has been estimated both in the controls as well as MNC-cauterized, allatetomised and ovariectomised insects, and the results are summarized in Table 1. When protein content analysed a few hours (0-day) after operation no change was observed in its content in the haemolpmph of controls and operated insects. During previtellogenic stage of the ovary the protein content of the haemolymph one day after operation showed no significant change in the values in all the experimental insects. However, 3 days after operation the MNC-cauterized and allatectomised insects showed significant changes in the haemolymph protein content while in the ovariectomised animals the values were not significant. In the ovary showing stage II and III vitellogenic stage the haemolymph protein content in all the experimental insects showed values that were significant when estimated 5 and 7 days after operation. In the spent stage of the ovary while allatectomised insects showed no significant change 9 days after operation, the MNC-cauterised and ovariectomised insects showed considerable changes in the haemolymph protein content which were very significant.

TABLE 1. Effect of MNC-cautery, allatectomy and ovariectomy on the haemolymph protein concentration during ovarian development in the adult *Plebeiogryllus guttiventris*[x]

Stages of ovarian development	days after operation	haemolymph protein concentration (g/100 ml)		
		MNC-cauterized (mean±SE)	allatectomised (mean±SE)	ovariectomised (mean±SE)
	0	0.89 ± 0.04** (0.90 ± 0.05)	0.90 ± 0.06** (0.90 ± 0.05)	0.91 ± 0.04** (0.90 ± 0.05)
Stage I Previtellogenesis	1	0.93 ± 0.02** (1.09 ± 0.08)	0.94 ± 0.03** (1.09 ± 0.08)	1.15 ± 0.06** (1.09 ± 0.08)
	3	0.99 ± 0 03* (1.90 ± 0.13)	1.19 ± 0.10* (1.90 ± 0.13)	2.01 ± 0.07** (1.90 ± 0.13)
Stage II & III Vitellogenesis	5	0.97 ± 0.04* (2.20 ± 0.18)	1.30 ± 0.09* (2.20 ± 0.18)	2.60 ± 0.07* (2.20 ± 0.18)
	7	0.92 ± 0.02* (1.97 ± 0.08)	1.17 ± 0.06* (1.97 ± 0.08)	3.07 ± 0.10* (1.97 ± 0.08)
Stage IV (Spent)	9	0.87 ± 0.03* (1.26 ± 0.06)	1.10 ± 0.04** (1.26 ± 0.06)	2.80 ± 0.05* (1.26 ± 0.06)

[x] = All insects operated after 8 hours of adult emergence; values represent mean of 7 animals; parantheses indicate controls; * = $p < 0.05$ ** = $p > 0.05$.

DISCUSSION

In insects, changes in the hamolymph protein concentration can be correlated with ovarian development (ELLIOTT & GILLOTT, 1977; KAMALAKANNAN, 1977). Moreover, fluctuations in the protein content of the haemolymph may be related to somatic growth when the oocytes are not competent to sequester proteins (GILLOTT & ELLIOTT, 1976; ELLIOTT & GILLOTT, 1977). This protein may be synthesised either in the fat body (vide reviews: TELFER, 1965; ENGELMANN, 1970) or follicle cells (ANDERSON & TELFER, 1969, 1970) or by both (RAMASAMY, 1983). The proteins thus formed are believed to reach the surface of the oocytes by intercellular and intracellular routes, and are incorporated as yolky materials by micropinocytosis. The present data revealed the involvement of neuroendocrine factors in the control of protein synthesis in *P. guttiventris*. Thus, the protein content of the haemolymph significantly decreased in the MNC-cauterized insects when compared to the controls. Therefore, the suggestion that the synthesis of protein may be controlled by median neurosecretory cells of the brain is supported by the findings in *Schistocerca gregaria* (HILL, 1962), *Tenebrio molitor* (MORDUE, 1965), *Periplaneta americana* (MILLS *et al*., 1966) and *Melanoplus sanguinipes* (ELLIOTT & GILLOTT, 1977).

3, 5 and 7 days after allatectomy the protein content of the haemolymph significantly decreased when compared to that of controls supporting the observations made for *Leucophaea maderae* (ENGELMANN & PENNEY, 1966), *Periplaneta americana* (THOMAS & NATION, 1966), *Rhodnius prolixus* (PRATT & DAVEY, 1972) and *Locusta migratoria* (GOLTZENE & HOFFMAN, 1974). The terminal oocytes had no protein granules in the allatectomised insects. These findings suggest that the synthesis as well as uptake of proteins by the oocytes are controlled by corpora allata (MCCAFFERY, 1976). The haemolymph protein content in the allatectomised insects was comparatively higher than that of MNC-cauterized insects. Alternatively, a gradual accumulation of protein content in the haemolymph of allatectomised insects was probably due to prior allatotrophic effect of the median neurosecretory cells of the brain. The effect of ovariectomy was examined since the protein content of the haemolymph mainly appeared to be related to egg development. Ovariectomy had resulted in a significant increase in the haemolymph protein content 5, 7 and 9 days after operation. It is inferred from this observation that the synthesised protein through MNC and CA principles remains not utilized by the target organs.

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AERODYNAMIC PARAMETERS OF A BLISTER BEETLE *MYLABRIS PUSTULATA*

G. Mohan Rao, C. Janaiah, N. Chari & Adeel Ahmad[1]

Department of Zoology, Kakatiya University, Warangal, India 506 009

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Wing loading values of a blister beetle, *Mylabris pustulata* range from 0.17—0.21 g/cm^2 and the aspect ratio values from 5.89—6.16. M_f/L^2 value is of 0.02—0.03 g/cm^2. The high aspect ratio (5.89—6.16) indicates that it is a moderate flier and possesses manoeuvrable flight. The calculated values of M I are in good agreement with those determined experimentally. Aerodynamic requirements in relation to flight performance are discussed.

(Key words: aerodynamic parameters, momenf of inartia, hovering flight, flight surface)

INTRODUCTION

Babu *et al.* (1978) reported the aerodynamic parameters of a pentatomid bug *Chrysocoris purpureus*. Gopalakrishna *et al.* (1983) accounted the role of flight surface in tethered flight of insects. Ahmad (1984) made a comparative account of aerodynamic parameters and flight surface design of insects, birds and bats. Hasan *et al.* (1984) have studied the aerodynamic parameters and design of flight surface of *Anopheles stephensi*. The aerodynamic forces on the elytra have been measured for rhinoceros beetle *Orycetes boas* (Burton & Sandeman, 1961) and the May beetle, *Melolontha melolontha* (Nachtigall, 1964). Hence the authors made an attempt to study aerodynamic parameters, moment of inertia of a beetle, *Mylabris pustulata*.

MATERIALS AND METHODS

Experiments were performed on 10 male and 11 female *M. pustulata*. The elytra of *M. pustulata* were stationary during the flight, helpful in balancing. The static parameters (Table 1) were determined by using a sensitive balance (model K. Roy, least count 0.1 mg) and a slide projector. The area of the wing was determined by considering the expression, $A \approx \pi\, lc/4$, and verified by a planimeter. Moment of inertia is determined by strip method of Norberg (1976). A mathematical expression was deduced for M I of the wings (Hasan *et al.*, 1984). The wings of *M. pustulata* are approximately elliptical in shape and the mass is more or less uniformly distributed throughout the wing. This method is similar to that followed by Ahmad (1982).

[1]Biophysics Laboratory, Department of Physics, Nizam College, Hyderabad, India 500 001.

RESULTS AND DISCUSSION

The average values of static and aerodynamic parameters are listed in Table 1 and are compared for males and females. The ratio of total wing mass (M_w) to the mass of male beetle (M_f) is 0.006, while in the case of females the ratio is 0.005. The low M_w/M_f values of females and males reveal high wing beat frequency to develop aerodynamic forces, leading to hovering flight. The fineness ratio (L_f / B_f), the ratio of the length of the flier and its breadth is more or less the same in both male (5.78cm) and female

TABLE 1. Static and aerodynamic parameters of *Mylabris pustulata.*

	Male		Female	
	mean	± S D	mean	± SD
Mass of the flier, M_f (g)	0.556	0.15	0.692	0.25
Wing length, l (cm)	2.0	0.15	2.17	0.26
Wing span, L (cm)	4.5	0.43	4.79	0.60
Wing area (two wings), A(cm^2)	2.99	0.46	3.11	0.73
Wing breadth, B(cm)	0.70	0.06	0.73	0.09
Length of the flier, L_f (cm)	2.37	0.26	2.5	0.25
Breadth of the flier, B_f (cm)	0.41	0.059	0.42	0.043
Fineness ratio, L_f / B_f	5.78	0.42	5.91	0.27
Mass of the wings, M_w (g)	0.0032	0.0009	0.0042	0.002
M_w / M_f	0.006	0.0015	0.0058	0.002
Wing loading, M_f/A (g/cm^2)	0.17	0.03	0.21	0.03
Aspect ratio, $2l^2/A$	5.89	0.18	6.16	0.69
M_f/L^2 (g/cm^2)	0.027	0.005	0.030	0.004
Moment of intertia (MI), (g/cm^2) (Strip method)	0.0024	0.0002	0.003	0.0002
Moment of inertia (MI), (g/cm^2) (Calculated)	0.002	0.0002	0.003	0.0002

(5.91 cm) insects according to their body weight. The low wing loading values in males (0.17 g/cm^2) are coupled with low aspect ratio (5.89), while the high wing loading values in females (0.21 g/cm^2) are coupled with high aspect ratio (6.16) along with the relatively low M_f/L^2 values ranging from 0.02—0.03 g/cm_2 indicating that they are highly manoeuvrable fliers. Wing loading is of the order 0.17 to 0.21 g/cm^2 thereby indicating a relatively high wing area in relation to mass of the insect. The wing loading is low as compared to birds and bats, suggesting the relative aerodynamic efficiency of the flier. Aspect ratio of male and female *M. pustulata* is in the range of 5.89 to 6.16 suggesting that the manoeuvrability is relatively higher in females. In *M. pustulata* hovering frequency ranges from 70—85 cps. Some Coloeptera posses myogenic flight muscles (PURANIK & CHARI, 1986). The moment of inertia, the measure of the resistance a body offers to a change in rotational motion about a given axis forms the basis for the calculation of kinetic energy of the rotating body. The moment of inertia of the flight surface *M. pustulata* is in the range of 0.0024 g/cm^2 to 0.003 g/cm^2 (Table 1). Further it can be noticed from the Table that the calculated values of MI are in agreement with those determined by strip method. Fig. 1 gives the plots between MI and strip number; surface density and strip number, which show the varia-

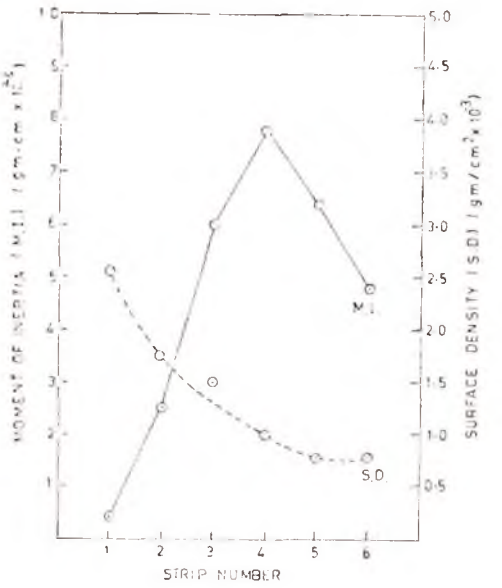

Fig. 1. Graph showing the relation between strip number and surface density (SD) and moment of inertia (MI)

tions in MI and surface density along the wing axis. The MI curve is a single bell shaped and the surface density shows an exponential decrease with the strip number. This meets the requirement for flight manoeuvrability by providing necessary rigidity at the wing base and flexibility at the appropriate points along the flight surface. This type of flight surface helps the flier to generate requisite amount of aerodynamic forces such as lift and thrust. However, the elytra contribution for left is about 15—20%.

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POPULATION DENSITY, BIOMASS AND SECONDARY NET PRODUCTION OF COLEOPTERANS IN A TROPICAL GRASSLAND

B. R. KAUSHAL & L. K. VATS*

Department of Zoology, Kumaun University, Naini Tal, India 263 002
*Department of Zoology, Kurukshetra University, Kurukshetra, India 132 119

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Population dynamics, biomass and secondary net production of coleopterans was studied in a grassland at Kurukshetra for a period of two years from June 1976 to May 1978. A total of 30 species belonging to 7 families were collectad. Maximum density on both stands was 1.6m−2m. Maximum biomass was 20.7 mg m^{-2} on stand I and 50.8 mg m^{-2} on stand II. Cumulative secondary net production was 49.73 mg m^{-2} on stand I and 95.26mg m^{-2} on stand II.

INTRODUCTION

There have been relatively few studies on population density and biomass of coleopterans both under temperate and tropical ecosystems (RICOU, 1967; RIEGERT *et al.*, 1974: LAMOTTE, 1975; VATS & SINGH, 1978), studies mostly confining to taxonomic composition (EVANS & MURDOCH, 1968; IGARSHI, 1973; PIMENTEL & WHEELER, 1973).

The aims of the present study is to report on population density, biomass and secondary net production of coleopterans from June 1976 to may 1978 in a tropical grassland.

MATERIALS AND METHODS

The study site is situated at the University Campus at Kurukshetra (29°58′ N and 76°51′E). The climate of Kurukshetra is monsoonic, with an average rainfall of 800 mm. During the study period, the mean maximum temperature varied from 21.3°C (January) to 37.8°C (June) while the mean minimum temperature ranged from 6°C (December) to 24.6°C (June). There are three wet months of rainy season (July to September) and nine dry months. The dry period is further divisible into a cool dry period from October to February (winter season) and a hot dry period from March to June (summer season).

Two types of vegetation were recognised. An area with mixed grasses was designated as stand I whereas an area dominated by the perennial grass, *Desmostachya bipinnata* was referred to as stand II. Details of the vegetation are given by GUPTA & SINGH (1982).

Population density was studied using removal-trapping method since the insects once trapped had the least chance to escape. For this purpose, a trap of 1.75m^2 with a small entrance (82 × 85 cm) on one side, 40 cm above the ground level was constructed. Wire gauze of 5 meshes per cm was fixed on the sides and top of the trap. It was carried from one sampling spot to another with handles fixed on the opposite sides. The trap was lowered randomly on the ground at ten different spots, five per stand. While moving the trap care was taken that tips of grass blades were not disturbed. The insects thus entrapped were collected, oven dried at 60°C, and weighed in a single pan electric balance (accuracy up to 0.1 mg).

Secondary production was calculated by using sampling data to compute the mean

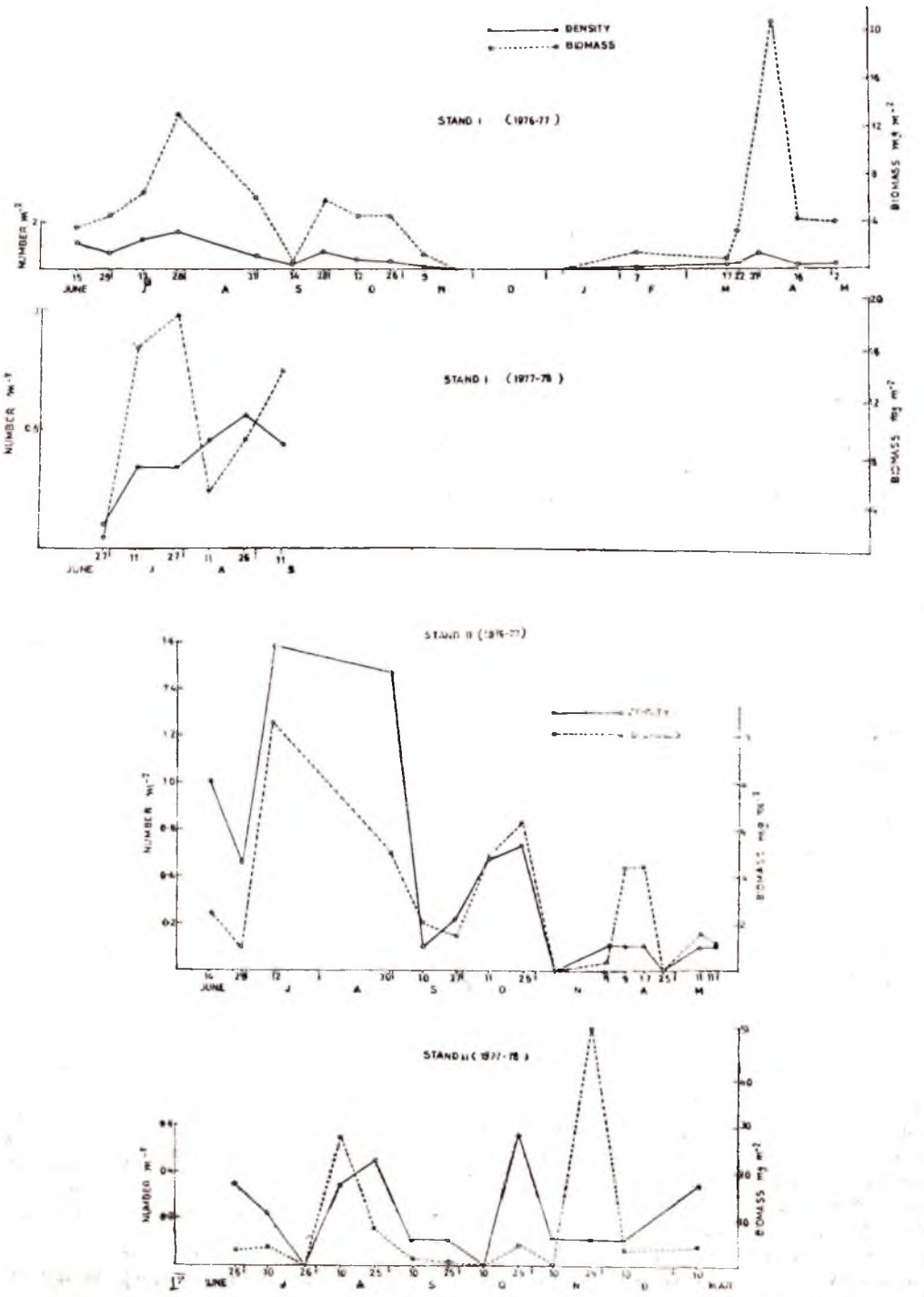

Fig. 1–4. Population density and biomass of coleopterans during 1976—1978.

biomass present during a sampling period. Production was calculated using WIEGERT's (1965) equation :

$$P = S + \sum_{i=2}^{n} \frac{(N_i + N_i - 1)}{2} \cdot (W_i - W_i - 1)$$

where : N_i = the number of insects present at time i; W_i = the mean weight per insect at i; i = the sample time; S = the standing crop at time i = 1. It was assumed that $N_i \leqslant N_i - 1$ and $W_i \leqslant W_i - 1$. When W_i was less than $W_i - 1'$ the production was considered as zero.

RESULTS AND DISCUSSION

Coleopteran species and their total number on two stands is given in Table 1. Of the 30 species collected, 9 confined to stand I and 11 to stand II, whereas 10 were common to both stands.

The number of coleopteran species reported by other workers are: 169 from an alfalfa field (EVANS & MURDOCH, 1968); 21 at Kawatabi, IBP area (IGARSAI, 1973) 111 in alfalfa community (PIMENTEL & WHEELER, 1973); 30 and 29 at Bridford and Michigan, respectively (JANZEN & POND, 1975). Thus number of species differ in different communities,

Coleoptera accounted for 2.58% and 0.78% of the total population density and biomass of Insecta in the grassland (KAUSHAL & VATS, 1983). Data on population density and biomass are presented in Figs 1—4. Population density of only adult coleopterans and not for larvae was studied as our studies mainly confined to aboveground insect fauna (KAUSHAL, 1979), Maximum population density on both stands was $1.6 m^{-2}$, whereas biomass values were 20.7 mg m^{-2} on stand I and 50.8 mg m^{-2} on stand II.

Dioryche sp. and *Mesomorphus* sp. had maximum density (0.68 m^{-2}) but the latter was only dominant in terms of biomass, 50.8 mg m^{-2} (KAUSHAL, 1879).

Low temperature in winter (December–January), high in summer (May–June) and low productivity during these periods resulted in the absence of coleopterans in both stands. PUTNAM (1963) and DEMPSTER (1975) also reported that low or high temperature, drought or excessive moisture, all affect the number of insects. Vegetation also plays an inportant part in the distribution of insects (CLARK *et al.*, 1967).

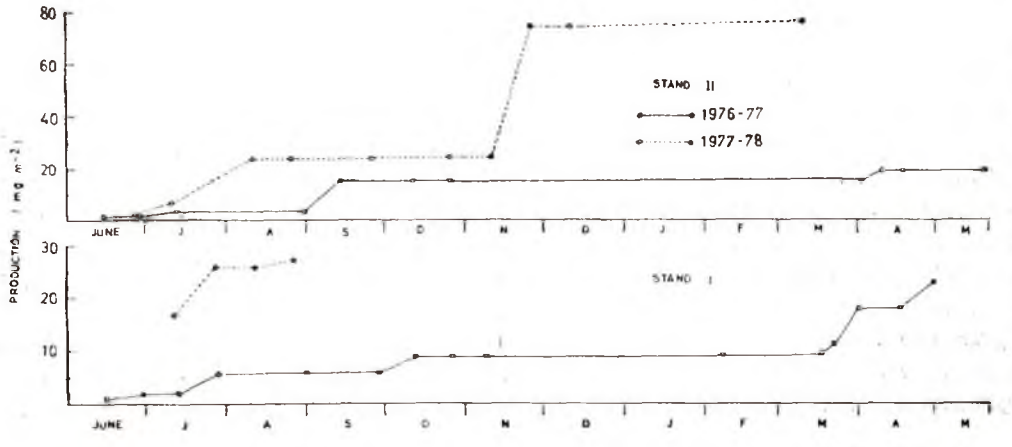

Fig. 5. Cumulative net secondary production of coleopterans during 1976—1978

TABLE 1. Coleopteran species, number of individuals collected and their per cent contribution on two stands during June 1976 to May 1978.

Taxon	stand I		stand II	
	number	%	number	%
Carabidae				
Colleida lativittis Chd.	1	1.02	—	
Dioryche sp.	26	26.53	4	5 06
Drypta argillacea Andr.	4	4.08	1	1.27
Mastex histrio F.	—	—	2	2.53
Ophionea indica Thunb.	—	—	1	1.27
Stenolophus smargulus var. *pustulatus* (Wied)	—	—	1	1.27
Staphylinidae				
Paederus fuscipes Curt.	4	4.08	2	2.53
Coccinellidae				
Brumus suturalis Fabr.	—	—	4	5.06
Callophora 9-maculata consortula	2	2.04	—	—
Coccinella septumpunctata L.	3	3.06	—	—
Epilachna vigintioctopuncta Fabr.	13	13.27	9	11.39
Exochomus uropygialis Muls.	—	—	2	2 53
Thea-bis-Octo-notata Muls.	1	1.02	—	—
Verania alardi	—	—	1	1.27
Tenebrionidae				
Mesomorphus sp.	9	9.18	13	16.46
Mesomorphus striolatus	—	—	2	2.53
Platynotus perforatus Muls.	1	1.02	—	—
Scleron reitteri Geb.	2	2.04	—	—
Chrysomelidae				
Aulacophora foveicollis Kust.	7	7.15	6	7.59
Diapromorpha turcica	—	—	1	1.27
Galerucella birmanica Jac.	—	—	2	2.53
Haltica cyanea Weber.	2	2.04	—	—
Monolepta bilineatus	—	—	5	6.33
Monolepta nigrobilineatus Mots.	7	7.15	8	10.12
Oides bipuncta F.	—	—	3	3.80
Corynodes perigrinus Fuess.	3	3.06	—	—
Lamiidae				
Pterolophia inexpectata Brun.	—	—	2	2.53
Curculionidae				
Myllocerus sp.	1	1.02	9	11.39
Myllocerus sabulosus Mshall.	2	2.04	—	—
Myllocerus variabilis Host.	10	10.20	1	1.27

In comparison to maximum density (1.6 m^{-2}) and biomass (50.8 mg m^{-2}) recorded in the present investigation mean density and biomass of coleopterans were 2.66 m^{-2} and 29.92 mg m^{-2} in natural grassland, respectively (RIEGERT *et al.*, 1974); 1.68 m^{-2} and 38.85 mg m^{-2} in a tropical savannah (LAMOTTE, 1975). Coleopterans were not so important in a tropical grassland (VATS & SINGH, 1978).

Vegetational composition and climatic conditions thus affect the number of insects in different communities.

Cumulative secondary net production in two stands calculated from field data is gived in Fig. 5. Production was more on stand II (95.26 mg m^{-2}) than on stand I (49.73 mg m^{-2}) because of higher population density. These values underestimate the total values as these do not include mortality data of insects that died during the course of investigation. Data on secondary net production of coleopterans are lacking.

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LIFE HISTORY, ECOLOGY AND PEST STATUS OF THE SAPLING BORER, *SAHYADRASSUS MALABARICUS* (LEPIDOPTERA, HEPIALIDAE)[1]

K. S. S. NAIR

Division of Entomology, Kerala Forest Research Institute, Peechi, India 680 653

(Received 20 November 1985)

The sapling borer, *Sahyadrassus malabaricus* (Moore) has an annual life cycle, with most moths emerging in late April to May, in the pre-monsoon season. Although eggs were laid soon after emergence, the new generation of larvae was found on saplings only about three months later when the larvae were 1.5—2.0 cm long, indicating that the early larval instars survived elsewhere and migrated to saplings later. The larva feeds on the bark of saplings, particularly on callus tissue in the vicinity of the tunnel mouth, under cover of a thick mesh-work of bark, wood and frass particles. Fifteen new hosts were recorded in this study, bringing the total to 50 species of woody shrubs and trees belonging to 22 families. *Trema orientalis* (Ulmaceae) was the most acceptable host, harbouring as many as 30 larvae per tree while multiple infestation was rare in other hosts. Predation by wood-pecker and infection by the fungus, *Metarhizium anisopliae* were recorded. In some 2 to 4 year old teak plantations studied, 6 to 61% of the saplings were attacked, but economic damage was negligible. However, plantations of *Albizia falcataria*, *Casuarina equisetifolia* and *Eugenia caryophyllata* suffered serious damage due to ring-barking.

(Key words: Sahyadrassus malabaricus, Metarhizium anisopliae, Hepialidae, sapling borer, forest plantations, teak)

INTRODUCTION

The larva of *Sahyadrassus malabaricus* (Moore) (Lepidoptera, Hepialidae) is a borer of forest tree saplings. It lives inside a tunnel along the pith of the main stem, and covers the tunnel mouth with a conspicuous mesh-work of wood, bark and frass particles (BEESON, 1941). In recent years, it has been increasingly noticed in yong plantations of teak, eucalypts and other forest tree species in Kerala. Except for brief references in earlier works (HAMPSON, 1982; LEFROY, 1909; FLETCHER, 1914; AYYAR, 1940) and a general description of the insect and its life history (BEESON, 1941), there is no published work on this species which is endemic to Peninsular India. The present study was undertaken to gather data on the life history, ecology and pest status of the species.

MATERIALS AND METHODS

The habits and life history were studied by frequent field observations in infested teak plantations. Additional observations were made on field-collected larvae rehabilitated on saplings of *Trema orientalis* within the Institute campus. All stages of larvae could be established readily on this host irrespective of the original host species. A hole just sufficient to accommodate the larva, was drilled on the stem at right angle. When placed near the hole, the larva entered into it, usually moving

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backwards. If the hole was not deep enough, it came out, deepened the hole by gnawing out wood particles and re-entered, posterior end first, and within an hour closed the entrance with a mesh-work of wood particles and silk.

The period of moth emergence was determined by trapping the moths emerging from the host. A trap developed for this purpose consisted of a square piece of plastic netting to which cloth borders were stiched. By means of strings inserted through folds on two opposite ends (as in a curtain), the net was tied around the infested stem portion like a cylinder, and the open ends were stapled together.

The host range was established from observations over several years in various parts of Kerala. The rate of infestation was determined by surveying a few selected plantations of teak and eucalypts. Since only infested plantations were surveyed, and these were selected on the basis of reports received from the Forest Department, the rates recorded do not represent the average. For teak, plantations surveyed were 1—5 year old, and generally all the saplings in every 10th row were examined. The sampling locations and the total extent of the plantation were as follows: Arippa, 1.8 ha. Kallar Valley, 6 ha; Kalady, 18 ha; Kothamangalam, 26 ha; and Parambikulam, 60 ha. For eucalypts, 1—2 year old plantations of three species were surveyed and generally all saplings in every 5th row were examined. The species, locations and the total extent were as follows: *Eucalyptus grandis*—Sultan's Battery, 12 ha; Peermade, 6 ha; *E. tereticornis*–Peermade, 6 ha; and *E. urophylla*–Peermade, 6 ha.

RESULTS AND DISCUSSION

Larval habits and nature of damage

In infested saplings the tunnel mouth and the surrounding area is covered by a conspicuous mat-work consisting of coarse, saw-dust like particles of wood and bark, spun together with silk (Fig. 1). Faecal pellets and moulted head capsules are often attached to this mat. This dome-shaped covering is here called a 'particle-mat cover' and abbreviated as PMC, for convenience. The tunnel mouth is generally located about 30 cm above ground on the main stem of saplings, but the height may vary from 5 to 60 cm. The larva excavates a long cylindrical tunnel, about its own diameter, longitudinally along the pith (Fig. 2). The top end of the tunnel is curved and opens to the outside while the bottom end is closed, and extends into the tap root if the sapling is small. Normally the larva rests with head towards the tunnel mouth. It can move either forwards or backwards with equal ease. The tunnel is used only as a shelter and the larva feeds on the bark and callus tissue around the tunnel mouth (Fig. 3). It browses in such a way that the lower bark layers are left intact at many spots, ensuring sustained regeneration of new tissues. Feeding takes place at night. If the PMC is removed, it is usually rebuilt overnight.

Usually the damage caused by this insect is limited to tunnelling of the pith and feeding of bark over a small patch or in an incomplete ring around the tunnel mouth. Some saplings break off at the point of injury and some get ring-barked (Fig. 3) resulting in death of the top portion.

Life history

Moths emerged between mid-March and mid-May, with most emergence occurring in late April and early May. BEESON (1941) recorded that moths emerged mainly in May and on into June. It is obvious that emergence occurs during the pre-monsoon season with small variations between years and localities.

The diagnostic features of the moth have been described by HAMPSON (1982). Some observations, not previously recorded, are given here. Measurements of a typical field trapped female moth were: wing span, 11 cm; body length from head

Fig. 1. The dome-shaped mat-work of wood particles and frass (PMC) covering mouth of the tunnel on a stem of *Cajanus cajan*. 2. L S of attacked portion of a teak sapling showing the larval tunnel larva at bottom. 3. A 16 month old teak sapling ring-barked by *S. malabaricus*. The PMC has been removed to show the central tunnel mouth and intense callus growth. 4. Multiple infestation of *S. malabaricus* on *Trema orientalis*. The black wavy line along the main trunk is a termite tunnel.

to abdomen, 5 5 cm. But there was large individual variation, some being about half the above size. Small saplings, paticularly of *Clerodendrum viscosum*, often harboured small pupae. At rest, the moth hangs vertically in a characteristic posture, supported by the first two pairs of legs. In the male, the third pair of legs, which is shorter and nonfunctional, possess scent glands which producce a sharp, pungent, mustard-like smell. The moths are sluggish during the day and do not fly even when disturbed. According to BEESON (1941) they are active for a short period at dusk. In laboratory cages, they lived for 3—5 days; the vestigeal mouth parts with atrophied proboscis show that they are not capable of feeding. Newly emerged females laid eggs when disturbed, often when held by thorax between fingers. Eggs were laid in a train at great speed; 5 to 6 eggs could be seen sticking out momentarily. While laying, the abdomen was often rotated in a circle, as if to disperse the eggs, and there were intermittent pauses. Eggs (unfertilised) were cream coloured when laid, turning black within an hour or two, spherical and about 0.5 mm in diameter. In one instance an unmated female laid 4,166 eggs in a laboratory cage. Evidently they are capable of laying several thousands of eggs. Some species of hepialids are credited to produce as may as 40,000 eggs per female (BEESON, 1941).

In most years all moths had emerged by mid-May from infested saplings but a new infestation of saplings was found only by mid-August, that is, about 3 months later. By then, the larvae were already 1.5 to 2.0 cm long. Generally, early stages of the larvae were not seen in the saplings thus infested. On rare occasions, between August and November, very small larvae were found on small branches of *Trema orientalis* or on the main stem of small teak saplings at heights much above the normal infestation sites of bigger larvae. Infestation of bigger larvae on the main stem appeared to build up suddenly over a few weeks starting August-September. These observations suggest that the early larval instars thrive elsewhere, probably on weedy ground vegetation, and later migrate to the host saplings. More detailed investigations are necessary to understand the habitats and behaviour of the early larval instars.

Full-grown larvae are large conspicuous caterpillars, 6 to 10 cm long, yellowish white in colour, and with deep-black head capsule. The first as well as parts of the second and third thoracic segments, and some dorsal sclerites of the abdomen are brownish. Rarely, larvae with a blackish general colouration were encountered, occurring in mixed population with other larvae. The significance of this colour variation is not clear.

Pupation occurred between mid-February and early April and prior to that the larva made a hole in the PMC across the tunnel mouth, evidently to facilitate escape of the emerging moth. It was not possible to determine the pupal period exactly, but it is estimated to be between 3 and 5 weeks. There was good synchronisation in the emergence of the moth population and there was no overlapping of developmental stages. After moth emergence, the pupal exuvia, 6—9 cm long, was usually seen sticking out of the PMC.

Host range

BEESON (1941) listed 30 host plants and an additional five were recorded by others(LEFORY, 1909; AYYAR, 1940; BROWNE,

1968; DAVID & KUMARASWAMY, 1978). Fifteen new hosts were recorded in this study, viz., *Cassia hirsuta* (*Caesalpineaceae*); *Chromolaena odorata* (Syn. *Eupatorium odoratum*) (Compositae); *Acacia pennata*, *Albizia falcataria* and *Calliandra callothyrsus* (Mimosaceae); *Eucalyptus grandis*, *E. tereticornis*, *E. urophylla* and *Eugenia caryophyllata* (Myrtaceae); *Anthocephalus chinensis* (Rubiaceae); *Solanum indicum* and *Solanum melongena* (Solanaceae) and *Sterculia companulata* (Sterculiaceae). Infestation was most common on *Clerodendrum viscosum* and *Trema orientalis*. *C. viscosum* (Syn. *C. infortunatum*) is a common shrubby weed, prevalent in most natural forests in Kerala, particularly in open areas. It usually occurs gregariously, in small patches. In one instance, out of 29 plants, 4—7 cm girth at base, examined in December 1978 in a roadside patch at Sultan's Battery, 21 were attacked; two of them harboured two larvae each, and one, three larvae. Such high incidence was common in *C. viscosum*. The other favoured host, *Trema orientalis*, is coloniser species common in open forests. On this host, both saplings and trees were infested, whereas on other hosts only saplings of girth range, 7—11 cm at base, were infested. In addition, multiple infestation was common in *T. orientalis* some medium-sized trees harbouring as many as 30 larvae (Fig. 4). Two dozen roadside trees along the Vazhachal–Orukombankutty road examined in February 1981 had an average of 10 larvae per tree (range, 2 to 20). Observations on *T. orientalis* within the Institute campus showed that in this species bark regeneration was quick and profuse, a characteristic, favourable to the insect.

A study of the host list shows that *S. malabaricus* is highly polyphagous, attacking about 50 species belonging to 22 families, viz., Acanthaceae, Boraginaceae, Caesalpineaceae, Casuarinaceae, Compositae, Euphorbiaceae, Gyrocarpaceae, Labiatae, Lythraceae, Malvaceae, Mimosaceae, Myrtaceae, Papilionaceae, Rhamnaceae, Rosaceae, Rubiaceae, Sapindaceae, Solanaceae, Sterculiaceae, Tiliaceae, Theaceae, Ulmaceae, and Verbenaceae. Absence of bark exudates is a common characteristic of these families, with the exception of Euphorbiaceae. Trees attacked in Euphorbiaceae are *Bridelia retusa*, *Macaranga indica* and *Mallotus philippensis*. Trees most commonly attacked belonged to the families Ulmaceae, Verbenaceae, Mimosaceae, and Myrtaceae, *Trema orientalis* (Ulmaceae) being the most acceptable,

Distribution and incidence in plantations

The geographical distribution of *S. malabaricus* is limited to Peninsular India, with other related species occurring in Assam eastern Himalayas and the neighbouring countries, Burma and Sri Lanka (BEESON, 1941). In this study, it was recorded from most places in Kerala, including hilly forest areas and the plains. In the plains it was mostly found on *Trema orientalis*. The species has also been reported from Tamil Nadu, Karnataka and Maharashtra (HAMPSON, 1982; LEFORY, 1909; FLETCHER, 1914; BEESON, 1941; DAVID & KUMARASWAMY, 1978).

The percentage of infested saplings and the total number of saplings examined in each location in the teak plantations were : Arippa, 6% (500 saplings); Parambikulam 10.5% (171 saplings); Kallar Valley, 13.4% (358 saplings; Kothamangalam, 31.8% (1232 saplings); and Kalady, 60.8% (1004 saplings). Corresponding figures for the eucalypt plantations were:

E. grandis Peermade, 10.3% (1829 saplings); Sultan's Battery, 11% (1200 saplings); *E. tereticornis* – Peermade, 1.1% (1142 saplings); *E. urophylla* – Peermade, 9% (924 saplings). As is noted earlier, these figures do not indicate the average rates of infestation as there were many uninfested plantations not included in survey. But it is obvious that teak and eucalypt saplings are highly susceptible to infestation. Infestations were also noted in some young plantations of *Albizia falcataria*, *Anthocephalus chinensis*, *Calliandra callothyrsus*, *Casuarina equisetifolia*, *Gmelina arborea* and *Sterculia companulata*. In addition, 4 to 5 year old plantations of clove (*Eugenia caryophyllata*) were found infested in the Kanyakumari District in Tamil Nadu.

In most plantations, infestation was noticed when the weed growth was cleared. Although no strict comparison was made, general observations suggested that plantations with dense weed cover were more likely to be infested. It appears that survival of the early instars is dependent on adequate vegetation cover on the ground which may provide favourable conditions for survival of the early instars.

Analysis of preliminary data on the spatial distribution of infestation within plantations suggest that the distribution was clumped when the percentage of infestation was comparatively low (eg. 16—22%), but not so when the percentage of infestation was high (eg. 42%). A study of the distribution of attack in a young teak plantation bordering a stream bank showed that more saplings were infested near the stream border. The mean percentage of infestation was 20.9 in the first 5 rows closer to the stream border, 8.7 in the next 5 rows, followed hy 3.2 and 3.1 in the subsequent 5-row groups, the difference between rows being statistiaally significant at $p < 0.01$ (chisquare test).

Natural enemies

Indirect evidence indicates predation by a wood pecker. A peck-hole similar to that made by a wood-pecker was noticed in some infested saplings across the lower end of the tunnel, where the larva rests during the day. No larva was found inside the tunnel although the PMC remained intact, suggesting that the bird had extracted the larva through the peck-hole. In February 1980 seven instances of bird predation was found among 177 infested teak saplings at Athirapally (Kalady Forest Division) and two, among 80, at Kaliar (Kothamangalam Forest Division). Rare instances of bird predation was also found on infested saplings of *Clerodendrum viscosum* and *Albizia falcataria*. In another instance, the larva had built a PMC over the peck-hole at the lower end of the tunnel, indicating an unsuccessful predation attempt. Infestation at lower levels of the stem, with the tunnel extending below the ground level offers adaptive value againt bird predation. When in the open, the larvae are readily attacked by many species of ants. Apparently, the PMC affords protection against ants and other predators and parasites.

A fungal parasite caused mummification of mature larvae and in some instances such larvae were seen projecting out of the tunnel mouth underneath the PMC. When kept in laboratory, white fluffy mycelial growth appeared on the surface of the mummified larvae. Conidial scrapings from such larvae yielded colonies of *Metarhizium anisopliae* when cultured in appropriate media. Infestation was noticed in one out of 180 larvae on teak sapling at Kalady In February 1980 and in

two out of 200 larvae in *T. orientalis* at Vazhachal in February 1981; it was not possible to enumarate the larvae which might have died inside the tunnel.

Pest status

In young teak and eucalypt plantations, in spite of the somewhat high incidence of the borer, sometimes reaching upto 61%. Most saplings were able to withstand the damage. In *Albizia falcataria*, *Casuarina equisetifolia* and *Eugenia caryophyllata* on the other hand, many of the attacked plants dried up above the point of attack due to ring-barking. In these species the larvae appear to feed more extensively, because of poorer growth of callus tissue on which they feed. In such species *S. malabaricus* eauses economic damage.

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OBSERVATIONS ON SPIDERS (ORDER:ARANEAE) PREDACIOUS ON THE COCONUT LEAF EATING CATERPILLAR *OPISINA ARENOSELLA* WLK. (= *NEPHANTIS SERINOPA* MEYRICK) IN KERALA: OCCURRENCE AND SEASONAL ABUNDANCE*

B. SATHIAMMA, S. P. JAYAPAL & G. B. PILLAI

Biological Control Laboratory, Central Plantation Crops Research Institute Regional Station, Kayangulam, Krishapuram, Kerala, India 690 533

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Twenty-six species of spiders belonging to twelve genera and six families were collected from the coconut palms infestod with *Opisina arenosella*. The hunting spiders including species of *Cheiracanthium, Clubiona, Marpissa, Phidippus, Plexippus, Rhene* and *Sparassus* and the weaving spider *Tatragnatha* were widely distributed. *Cheiracanthium* constituted nearly 21% of the total spider fauna on the coconut palms. Four species were noted as important predators of *O. arenosella*. Spiders occurred in the field almost throughout the year with maximum population during July—August.

(Key words: coconut, *Opisina arenosella,* spiders)

INTRODUCTION

Opisina arenosella Wlk. is one of the key pests of the coconut palms in many parts of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Gujarat and Maharashtra. Several parasites and predators have been documented effecting the natural suppression of *Opisina* population. Spiders constitute the dominant group of predators which exert considerable check on this pest. NIRULA (1956), MENON & PANDALAI (1958) and DHARMARAJU (1962) also had made mention of some species of spiders prevalent on coconut leaves infested with *O. arenosella*. However, no systematic attempts have been made so far to identify and study in detail the exact role of the spiders as biocontrol agents of the pest.

Our surveys during 1981—1983 in coconut gardens infested with *O. arenosella* in the Alleppey and Quilon districs of Kerala have revealed the prevalence of a rich fauna of spiders. Some are voracious feeders consuming a large number of caterpillars of *Opisina*. There are many others whose economic importance is not fully known. The main objective of the present study was to identify the spiders associated with *Opisina* infested coconut palms and to study their seasonal occurrence in the field.

MATERIALS AND METHODS

Opisina- infested gardens comprising nearly 800 coconut palms of the age group 5 to 10 years were selected for the study. Twenty per cent of the palms were marked as sample for observation and in each palm two sample leaves of the lower whorl were observed. Data on the population of the spiders present were recorded every fortnight.

RESULTS AND DISCUSSION

Occurrence:

Among the spider fauna collected from *Opisina* infested coconut palms,

*Contribution No. 454 of Central Plantation Crops Research Institute, Kasaragod 970 124, Kerala, India.

twentysix species belonging to 12 genera and six families were identfied and listed in Table 1. The hunting spiders viz. *Cheiracanthium* sp., *Clubiona drassodes*, *Marpissa dhakuriensis*, *M. tigrina*, *Phidippus bengalensis*, *Phidippus* spp., *Plexippus paykulli*, *Rhene indicus*, *R. khandalensis*, *Sparassus* sp. and the weaving spider *Tetragnatha andamanensis* were widely distributed in all the areas combed during the study. Salticid spiders were more common than the other groups of spiders present on *Opisina* infested coconut palms.

In number, *Cheiracanthium* sp. topped the list (Table 2). Nearly 21% of the total population comprised this species. *Marpissa tigrina* constituted 7%, *Sparassus* sp. 6%and *Rhene indicus* 5% of the total population of the spiders. Other common species of spiders present on *Opisina* – infested coconut leaves were *Tetragnatha andamanensis*, *Phidippus bengalensis*, *Neoscona elliptica* and *Cheiracanthium melanostoma*. Besides these species, four species of *Marpissa*, three species of *Phidippus* and a number of other spiders co-existed with the population of *O. arenosella* on

TABLE 1. Spider fauna associated with *Opisina arenosella* – infested coconut palms.

Family	name of spider
Araneidae	*Argiope catenulata* (Doleschall)
(= Argiopidae)	*Larinia javasankari* Biswas
	Neoscona bengalensis Tikader and Bal
	N. elliptica Tikader and Bal
Clubionidae	*Cheiracanthium melanostoma* Thorell
	Cheiracanthium sp.
	Clubiona drassodes Cambridge
Gnaphosidae	*Poecilochroa barmani* Tikader
Salticidae	*Marpissa anusuae* Tikader and Biswas
	M. dhakuriensis Tikader
	M tigrina Tikader
	Marpissa sp. (Coll. No. 67)
	Marpissa sp. (Coll. No. 68)
	Phidippus bengalensis Tikader
	Phidippus sp. (Coll. No. 7)
	Phidippus sp. (Coll. No. 26)
	Phidippus sp. (Coll, No. 61)
	Plexippus paykulli (Aud.)
	Rhene danieli Tikader
	R. indicus Tikader
	R. khandalensis Tikader
Sparassidae	*Sparassus* sp.
Tetragnathidae	*Tetragnatha andamanensis* Tikader

TABLE 2. Seasonal abundance of spider population on *Opisina arenosella*–infested coconut palms.

Name of spider	Jan.	Feb	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Argiope catenulata	0	0	0	0	0	0	0	1	0	0	0	0
Cheiracanthium melanostoma	0	1	0	13	8	8	7	14	0	2	0	10
Cheiracanthium sp.	22	16	39	16	22	23	89	61	28	39	14	29
Clubiona drassodes	0	0	0	1	1	1	7	0	3	3	0	0
Larinia jayasankari	0	0	0	0	0	0	1	1	1	0	0	0
Marpissa anusuae	0	0	0	0	0	1	8	0	0	0	0	0
M. dhakuriensis	0	0	1	1	0	0	7	0	0	4	1	0
M. tigrina	0	2	3	16	9	7	25	25	13	21	5	13
Marpissa spp.	0	0	0	0	0	0	1	0	1	1	2	0
Neoscona elliptica	0	0	0	0	0	0	4	1	0	0	0	0
Phidippus bengalensis	0	0	2	10	9	9	13	12	11	4	4	4
Phidippus spp.	0	1	7	4	12	13	6	18	6	9	4	6
Plexippus paykulli	0	0	0	0	0	0	1	6	2	1	0	0
Rhene danieli	0	0	0	0	0	0	0	0	0	0	0	1
R. indicus	0	0	2	6	7	3	18	23	16	19	1	0
R. khandalensis	0	0	0	0	0	0	0	2	2	0	0	0
Sparassus sp.	3	7	6	6	4	12	17	18	5	11	6	17
Tetragnatha andamanensis	14	3	3	0	7	5	20	19	14	26	12	23
Unidentified spiders	128	78	42	32	51	56	38	60	31	30	24	179

coconut palms The economic importance of some of these species is yet to be ascertained. As regards the predacious habits on caterpillars of *O. arenosella*, *Cheiracanthium* ap., *Sparassus* sp., *Rhene indicus* and *Marpissa tigrina* are very important and they consumed the immature as well as adult stages of the pest.

Seasonal abundance:

Spiders were present on *Opisina*–infested coconut palms almost throughout the year (Table 2). Maximum spider population was observed during July–August and minimum during February to March. *Cheiracanthium* sp. occurred at its maximum level during July; *M. tigrina* during July and August; *Sparassus* sp. during July and December and *R. indicus* during August. It is interesting to observe that the population of *O. arenosella* was normally at a lower level during July–August period, when the populations of spider fauna, particularly the highly predacious ones, were abundant. Similarly during February-March period when the spider fauna was less abundant, build up of population or *Opisina* was observed.

This clearly brings out the significant role the spider community plays in the natural suppression of *Opisina* population in the field.

Spiders constitute one of the dominant groups of predators exerting natural suppression of many pest species. SPECHT & DONDALE (1960) described 34 species of spiders associated with apple orchards. Spiders were observed to have a definite seasonal succession checking the cotton insect pests from early growth state sill maturity of the crop (WHITCOMB *et al.*, 1963). They also play and important role in the control of insect pests of grain sorghum (BAILEY & CHADA, 1968). BARRISON & LITSINGER (1984) listed 217 species of rice field spiders from Asia and identified 51 species from the philippines, ten of which are dominant predators on rice pest. Observation on the spiders fauna of coconut gardens in association with *O. arenosella* and their impact on natural suppression revealed that the spiders play a vital role in the biological suppression of the pest. As such, conservation of these biocontrol agents has become quite imperative.

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BRIEF COMMUNICATION

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